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SOLID WASTES LANDFILL STABILIZATION

Ralph Stone and Company, Incorporated
Los Angeles, California

1968

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SOLID WASTES LANDFILL STABILIZATION

An Interim Report

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Consumer Protection and Environmental Health Service

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Since this is an interim report of progress, the conclusions and recommendations presented should be considered as preliminary in nature, pending completion of the project and final evaluation of findings.

SOLID WASTES LANDFILL STABILIZATION

An Interim Report

By Ralph Stone and Company, Inc., Engineers
For the City of Santa Clara, California
under Grant No. DOI-UI-00018

Details of illustrations in
this document may be better
studied on microfiche.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Consumer Protection and Environmental Health Service
Environmental Control Administration
Solid Wastes Program
Cincinnati
1968

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PREFACE

An estimated 800 million pounds of solid wastes of all types are produced in the United States every day. What to do with these solid wastes, how to dispose of them without needlessly endangering public health and welfare, and how to recover and reuse valuable materials now "thrown away" are among the most challenging and perplexing of current national problems. Because of lack of suitable planning, interest, and public understanding, these problems have reached such proportions that nationwide attention is demanded and action for the development of adequate solutions must be taken.

Intensified action concerning these problems was made possible by the Solid Waste Disposal Act, Title II of Public Law 89-272, which was signed by the President on October 20, 1965. This legislation directs the Secretary of the Department of Health, Education, and Welfare to initiate, encourage, and support a national program aimed at discovering and evaluating better methods of coping with the solid waste problem.

The Secretary is authorized (1) to conduct and support research on the nature and scope of the problem, on methods of more safely and efficiently collecting and disposing of solid wastes, and on techniques for recovering from solid wastes potentially valuable

materials and energy; (2) to provide training and financial and technical assistance to local and State agencies so that they can survey their needs in the solid waste area and plan for the development and staffing of programs capable of meeting those needs now and in the years to come; and, (3) to encourage and support projects that may demonstrate new and improved methods of solid waste collection, handling, and disposal.

To carry out these responsibilities, the Solid Wastes Program was established. Among the responsibilities with which the Program is charged is that of providing grant support for demonstrations relating to the development and application of new and improved methods of solid waste collection, storage, processing and ultimate disposal; and also for studies and investigations that may lead to a demonstration of improved disposal practices, or may provide solutions for regional or national solid waste disposal problems. Associated with this is the responsibilitiy of collecting and making available by appropriate means the results of, and other information pertaining to, such federally supported demonstrations, studies and investigations.

Accordingly this report has been reproduced to disseminate as widely as possible the latest available information and findings of a project that has received grant support from the Solid Wastes Program. It is hoped that it will provide those working in this field with useful information that will be of assistance in developing approaches to the solutions of their solid waste disposal problems.

This is an interim report of project progress, and additional work is currently underway to complete the project as identified in the abstract included herein. Additional progress reports, when received, will also be made available by the Solid Wastes Program for widespread distribution and use. The final report will be issued as a Public Health Service publication.

-- RICHARD D. VAUGHAN
Chief, Solid Wastes Program

ABSTRACT OF DEMONSTRATION GRANT NO. DOI-UI-00018

TITLE: Land Reclamation by Accelerated Stabilization and Related Studies of Compactor Equipment

GRANTEE: City of Santa Clara, California

PROJECT DIRECTOR: Ralph Stone, President
Ralph Stone and Company, Inc., Engineers
10954 Santa Monica Boulevard
Los Angeles, California 90025

DATE PROJECT STARTED: June 1, 1966

DATE PROJECT ENDS: May 31, 1969

OBJECTIVES: 1) to demonstrate the use of aeration in sanitary landfills to provide more rapid stabilization, increased capacity, and land reclamation for construction and other uses; and, 2) to compare the densities achieved in sanitary landfills using various types of compaction equipment.

PROCEDURES: The project will be carried out by Ralph Stone and Company, Inc., Los Angeles, California, over a three-year period. Test cells will be constructed and operated to demonstrate and compare conventional anaerobic sanitary landfill procedures with two types of aerated landfills, and their respective efficiencies in reclaiming land for industrial park use. One aerobic test cell will demonstrate the principle of composting and the second will demonstrate the principle of controlled high-rate oxidation to achieve an oxidized residue suitable for final land disposal. The proposed program is divided into the following three phases:

Phase 1 - Demonstration of the method of reclaiming landfills by rapidly oxidizing the refuse to a residue and comparing the results of this process with the composting cell and the conventional anaerobic control cell.

Phase 2 - Refinement of this process, supplemented by additional studies.

Phase 3 - Demonstration of full-scale aerobic or other improved disposal methods, industrial park land reclamation, and development of appropriate cost and land reclamation maintenance experience.

The relative effectiveness of a D-9 caterpillar and an F. W. Wagner WC-17 rubber-tired compactor in compacting domestic refuse will be demonstrated. The compaction obtained using an SF-17 Wagner steel-tired compactor will be demonstrated and compared to that obtained with the previous equipment. *

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* Mention of commercial products does not imply endorsement by the U.S. Department of Health, Education, and Welfare.

CITY OF SANTA CLARA/U.S.P.H.S. DEMONSTRATION

LAND RECLAMATION BY ACCELERATED STABILIZATION

Project Number 1-D01-SW-00018-01

First Annual Progress Report to

DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
UNITED STATES PUBLIC HEALTH SERVICE
SOLID WASTES PROGRAM

June 1, 1966 to May 31, 1967

Project Engineers

Ralph Stone and Company, Inc., Engineers
10954 Santa Monica Boulevard
Los Angeles, California 90025
(213) 478-1501, and 879-1115

For

City of Santa Clara
City Hall
Santa Clara, California

I-G

RALPH STONE AND COMPANY, INC. · ENGINEERS
10988-4 SANTA MONICA BOULEVARD · LOS ANGELES, CALIFORNIA 90025 · 478-1501 · 870-1158

31 August 1967

AIR MAIL

Mr. Richard Vaughan, Chief
Solid Wastes Program
U. S. Public Health Service
222 East Central Parkway
Cincinnati, Ohio 45202

Attention: Mr. Eugene Herson, Staff Engineer
Demonstration Activities

Subject: USPHS/City of Santa Clara
Demonstration Grant Number 1-D01-SW-00015-01
Final Report, 1966-67 Period

Gentlemen:

Forty (40) copies of the City of Santa Clara Demonstration Annual Report, covering the first twelve months work (1966-67) under the subject grant to demonstrate land reclamation by accelerated stabilization, is herewith submitted. This progress report is being presented for your review and comments and is also intended for use by your technical group for information purposes.

Respectfully submitted,

RALPH STONE AND COMPANY, INC.

Ralph Stone
President

RS:ETC:da
Enclosure

cc: City of Santa Clara

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2.0 FOREWORD

In June 1966, the City of Santa Clara initiated work on this three-year demonstration of land reclamation by accelerated stabilization. The general objectives of the program are to reduce sanitary landfill health hazards and problems by controlled high rate oxidation of solid wastes; increase landfill disposal capacity; stabilize wastes; minimize or eliminate odors and nuisances; improve waste reclamation technology; and study other effects of accelerated decomposition.

Matching funds were provided by Public Health Service Grant Number 1-D01-SW-00018-01.

Two aerobic test cells have been constructed, including provision for controlled aeration of the solid wastes. One cell will demonstrate in-situ aerobic treatment and the second will demonstrate controlled, high rate oxidation.

In addition, settlement/compaction tests are being conducted within an area of conventional anaerobic fill, natural ground and aerobic and stabilized fills.

Six months of support studies for the full-scale demonstrations have been provided by eight separate pilot plants, investigating various operating parameters.

The demonstration is being undertaken by the City of Santa Clara's Department of Public Works and Utilities at their Coffin Road Landfill and at the Project Engineer's laboratories.

3.0 ACKNOWLEDGMENTS

This demonstration has been supported by the United States Public Health Service, Solid Wastes Program, Demonstration Grant 1-D01-SW-00018-01, in cooperation with the City of Santa Clara, California

Mr. Eugene Herson, Staff Engineer, Demonstration Activities, has been the technical representative. Similarly, Mr. S. M. Cristofano, Director of Public Works and Utilities, has acted as the City of Santa Clara's solid waste project coordinator. Under his direction, the City has provided personnel, equipment, and related support facilities for carrying out the routine field demonstration work program. Mr. Joseph Shilts, former Street Superintendent (June 1, 1966 through December 31, 1966), Mr. William Bradley, present Street Superintendent, and Mr. Jerry Scott, Assistant Street Superintendent, have enthusiastically directed the City's day-by-day efforts. The City Council has sponsored the demonstration program through Mr. D. R. Von Raesfeld, City Manager, who is also designated as the City's authorized official.

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4.0 SUMMARY

The City of Santa Clara in collaboration with Ralph Stone and Company, Inc., Engineers, performed the necessary field work. The Stone organization completed the special pilot plant studies in its laboratory.

The field facility was constructed during the year June 1, 1966 through May 31, 1967. City forces were responsible for the cell excavation, related earthwork, and extension of utilities to the test site; a local contractor built the aeration system. Shakedown tests were initiated late in May, 1967. The significant field results are:

1. Approximately 25 percent expansion occurred when a one-year old anaerobic landfill 15 ft deep was excavated and recompacted.

2. The refuse used for the field demonstration was typical residential refuse, exclusive of wet garbage, and consisted primarily of paper and garden trimmings. Based on sampling, it was found to have a more or less uniform dry weight composition throughout the year. However, the moisture content was substantially higher in the spring than in the fall.

The first year program also permitted pilot plant test work that supported the technical feasibility of both both biological decomposition and high rate underground incineration within an engineered landfill. However, many complex operating and economic factors remain to be investigated. Therefore, the pilot studies are being continued to generate additional cost and technical data for analytic purposes. Important pilot plant findings are:

1. Biological oxidation required both controlled aeration and moisture. The pilot studies, although affected by the ambient environment, have improved operating technology and defined potential problem areas for the large scale field demonstration.

2. Several parameters for underground incineration were established.

(a) Refuse with a moisture content less than 20 percent ignited readily. Ignition was achieved with some smoldering with a moisture content between 20 and 30 percent.

(b) Pre-drying and pre-heating effectively reduced the moisture content, thereby improving ignition and increasing the subsequent rate of oxidation.

(c) As the burning face advances in the refuse, moisture is driven out of the adjoining refuse, indicating that on a large scale an underdrain may be necessary to evacuate the water.

(d) The type and density of refuse being incinerated, in addition to moisture content, dictate the rates of aeration and oxidation.

(e) The rate of aeration must be adequate to prevent partial oxidation of the waste material as evidenced by carbon monoxide production.

(f) Two of the factors that control the maximum rate of aeration in a large scale demonstration are odor control and efficient oxidation rates.

(g) Moisture content of the soil cover assists in satisfactory filtration of odors, smoke, and other air contaminants from the oxidizing refuse.

(h) It appears practical to use refuse as a filter medium while simultaneously pre-drying and heating the refuse for oxidation.

3. Laboratory pulping of paper, leaves and grass demonstrated an alternate method of sizing solids for transporting by water carriage, with possible separation for reclamation or ultimate land disposal.

5.0 THE SANITARY LANDFILL SITE

5.1 General The full-scale demonstration program is being accomplished at the City's 73.2 acre sanitary landfill. As indicated on Plate I, the landfill site is about 4-1/2 miles south of the upper reaches of San Francisco Bay. The natural ground elevations range from 9 to 16 ft above sea level.

The site meets the normal criteria for a sanitary landfill; it is centrally located and is accessible by paved roads; the soil is easily excavated; a public water supply and electrical power are provided for test service; fencing allows adequate protection from public intrusion; and the site is an isolated area with limited residential habitation. The low lying lands are improved by the subsequent filling and grading program.

The landfill has been in operation since 1965. It is bounded by Lafayette Street on the east, privately owned land on the north, Coffin Road and a Santa Clara County Flood Control District channel on the west, and a 94.4 acre parcel which the City has an option to purchase on the south. These two parcels are referred to as Parcels "A" and "B" respectively on Plate II. The entire 168.6 acre area is zoned for manufacturing, assembly and processing industries.

5.2 Service Area The site is located within a six-mile radius of the City Halls of Santa Clara, Sunnyvale and San Jose (see Plate I); it is less than two miles north of the Bayshore Freeway. Initially, the primary service area will be the City of Santa Clara with an estimated 1965 population of 85,000. However, because of its close proximity and

easy access to a much larger service population, many residents and industrial producers from nearby communities are using the landfill.

5.3 Geology The Santa Clara Valley is a downdropped block separated from uplifted mountains by complex faulting. The site is underlain by up to 1,000 ft of upper Pleistocene and Recent sands, gravels and clays. Marine fossils in blue clays taken from 300 ft in the Alviso area indicate this was once an arm of San Francisco Bay. More recent alluvial fan and flood plain deposits now constitute the surface cover.

5.4 Soils Proximity of the land reclamation site to Saratoga Creek which flows into San Francisco Bay and to the Guadalupe area indicates the existance of an alluvial fan and flood plain sediment consisting of fine to medium grained permeable soils. The soil is generally brown and tan silt with a thin mantle of fine sandy clay.

5.5 Land Subsidence Area-wide ..nd subsidence at the average annual rates of 0.27 ft from 1948 to 1960 and 0.33 ft from 1960 to 1965 is attributed to ground water overpumpage and the resulting compression of the deep clay horizons. The rate of subsidence has reportedly increased in the last two years. No salt water encroachment has yet been observed.

The amount of future subsidence is dependent upon the subsurface recharge and pumping rates; since subsidence is expected to continue until the overpumpage is stopped, it is necessary to fill any areas that are to be used for industrial sites or other higher type land uses.

5.6 Ground Water and Water Supply In December 1965, the ground water was observed 8 ft below the surface throughout the landfill site. This water is of minimal quality. Two wells are located at the

site; however, neither could be developed to provide a dependable water supply for this demonstration. The City has extended the public water system to the site to ensure an adequate source of water for the demonstration program.

5.7 Climate The climate of Santa Clara is relatively mild and temperate. Neither freezing temperatures nor temperatures exceeding 100°F are often experienced. The average annual rainfall is about 20 in and normally is concentrated in January through April. The rainfall, since initiating this demonstration program, has been sporadic from November 1966 through May 1967. It is tabulated in Table 9.

5.8 Statutory Landfill Requirements The California State Water Quality Control Board, in Resolution No. 713 adopted on December 16, 1965, prescribed requirements for the landfill site to preclude the occurrence of nuisances and pollution of ground water and to define the nature of the wastes to be accepted for disposal at the site. A copy of the resolution is contained in Appendix 3 of this report.

6.0 REFUSE AND SOIL

6.1 Refuse Source Refuse used to fill the demonstration cells originates in the residential areas of the City of Santa Clara. Collection vehicles containing other materials, such as construction, demolition and industrial wastes, are being excluded from the test site. Weekly rubbish collection is provided by the City's nine 26 cu yd packers. On a normal day the amount of refuse collected averages between 7 and 7 1/2 tons per truck.

6.2 Refuse Characteristics Refuse is being sampled as the demonstration cells are filled. General records of the seasonal variation in refuse composition, moisture content, volatile matter and other pertinent characteristics are being developed. As indicated by Table 8, the general composition of refuse delivered to the site has not exhibited major variations from spring to fall except for moisture content. On a dry weight basis, about 35 percent of the refuse placed in the aeration cells is garden trimmings, 55 percent is paper, 3 percent is plastics and 7 percent is metals, glass, ceramics and other inerts. The average moisture content has ranged from 71 percent in the spring to 15 percent in the fall. Volatile content averages about 84 percent on a dry weight basis.

6.3 Soil Characteristics As previously described, the top soil is fine, sandy clay overlying a clayey silt subsoil. This material is normally used to provide 24 in of final cover on the landfill. As available, asbestos cement and certain other inert industrial waste and demolition products are used to supplement this cover material to provide a surfacing course for winter access and to exclude surficial drainage from the fill.

7.0 CELL CONSTRUCTION

7.1 Anaerobic Test Cell Essentially, this test consisted of excavating an existing anaerobic cell and then recompacting the excavated refuse into a new cell. A 30 ft wide by 100 ft long section of a cell, completed in November 1965, was excavated to a 7 ft refuse depth. The D-9 tractor which accomplished this job encountered no significant difficulty in opening the cell and moving the refuse. The refuse was piled into a conical mound. The old fill material created noxious and characteristically putrid odors which were especially severe when the tractor was moving the freshly exposed refuse. When the tractor construction stopped, the odor level diminished. A special survey indicated that five miles upwind low level characteristic odors could be observed due to a prevailing one to two mph velocity wind and temperature inversion. However, no complaints were received and the test received no special notice.

The freshly excavated refuse was moist; newspapers, tin cans and plastics showed minimum decomposition and could be readily identified; grass cuttings had turned brown; woody vegetation indicated only minor decomposition; and cans and boxes were well compressed, indicating good compaction in the original landfill construction. As soon as the survey crew completed their topographic work, the refuse was placed in a newly prepared cell in normal 1 to 2 ft layers and carefully re-compacted. The new cell was then quickly covered to prevent further odors or fly production. No flies were observed within the 56 hour test period.

The volume of refuse excavated from the old cell was determined to be 530 cu yd. The volume of re-compacted refuse in the new cell was 667 cu yd for a net expansion of 25.6 percent. This compares favorably with observed settlement compaction for one year measured at the Spadra, Walnut, California landfill. Representative test refuse samples were obtained for analyses, and the results are summarized in Table 8.

7.2 Preload Test Cell The purpose of the preload test is to determine the foundation and settlement characteristics of a normal anaerobic landfill when supporting a one kip per sq ft load. Technical information of this nature may aid in stabilizing sanitary fills for higher uses. The settlement characteristics of this loaded cell will be compared with those of various compaction procedures, a clean earth fill, natural soil and oxidized residue. This testing program, which was started in June 1967, is described in Appendix 7. Results will be described in subsequent reports. Future preload tests will be accomplished in conjunction with the supplemental compaction studies, Project Number 3-D01-UI-00018-02S1.

7.3 Aerobic Cells As shown on Plate III, the demonstration cells were located to minimize interference with the City's normal landfill operation. Essentially, the aerobic test cells are subdivided into two areas: the aeration cell area, into which air is distributed into the refuse, and the residue cell area for disposal of the oxidized waste residue. Two separate aeration cells have been constructed to date. Initially, biological oxidation processes are being investigated in these cells.

The residue cells are adjacent to the aeration cells. The operational sequence and the relationship between the aeration and residue cells are illustrated on Plates IV and VI.

7.3.2 Excavation The site is relatively flat and at approximately Elevation 12 ft mean sea level (MSL). Since the finished grade for the landfill is planned for about 17 ft MSL, it was necessary to resort to excavation into natural earth with a build up of compacted earthen berms around the cells. The end slopes of the cells are no steeper than 2:1 to permit entry and exit of equipment; excavated side slopes are about vertical; embankments are no steeper than 1-1/2:1. To develop maximum volume of aerated refuse per unit cost of aeration system, the side walls of the aerated cells were built up to a 17 ft height. The bottom and top of the aerated test cells measure about 50 ft by 200 ft, and 85 ft by 270 ft respectively. The residue cells will be approximately 450 ft by 300 ft and 350 ft by 250 ft and about 13 ft deep.

7.3.3 Aeration System The aeration system is illustrated on Plate V and consists of two underdrain systems, a blower, valving and appurtenances. The underdrains, which are designed to distribute air throughout the aerated cells,are closed loops of 4 in diameter perforated, vitrified clay pipe. Each is composed of two parallel 192 ft lines crossed at right angles by 33 lines on 6 ft centers. The aeration piping was laid in trenches 12 in wide by 12 in to 15 in deep and was backfilled with select gravel. An 8 in steel pipe conveys the air from the blower to the underdrains described above.

An industrial exhauster rated to discharge 1400 cfm at a 12 in static pressure was installed to supply air to the cells. Variable speed sheaves vary the output from about 1200 to 1700 cfm. The interior surfaces of the blower were epoxy-lined for corrosion protection. A control relief valve was provided to reduce air delivery as required. A time clock and other automatic controls are included in the electrical system to vary the operating cycle as required.

The construction of the aeration system was by private contract, let for public bid in accordance with standard City of Santa Clara practices and modified to comply with Federal regulations. The lowest responsible bidder, Steve Eachus Construction Company, was awarded the contract. Early rains delayed the start of construction until January. About one week after the contractor initiated the construction, heavy rains washed out much of the initial work. The City and the contractor cleaned up the water-damaged underdrains and construction was again initiated in early March. However, rains once again washed out the construction. The rainfall factor is especially critical because of an impervious hardpan and a high water table at the site. Further sporadic rainfall weather conditions prevailed through the end of April. The contractor completed construction of the aeration system in May and preliminary shakedown tests were initiated.

7.3.4. Access Manways At the edge of each aerated cell, a manway has been constructed to provide access for observing bottom drainage, measuring internal environment and collecting fill samples.

The manways consist of 48 in diameter steel pipe, 20 ft long, with numerous openings cut into the side for access to the cell.

The manways will be covered with an air-tight, neoprene-coated nylon tarpaulin. Gas conduits and electrical leads will be carried outside of the enclosure and housed in a wooden box flush with grade for convenience in taking samples. These preparations will insure that the internal environment of the cell will remain unchanged during the sampling process. Surface drainage will be diverted from the access well.

7.3.5 Water Supply and Irrigation System The City of Santa Clara constructed a water main to the demonstration site for irrigation and fire protection. A portable sprinkler system was designed to irrigate an area 70 ft by 230 ft. The irrigation system, constructed of thin wall aluminum pipe, is sufficiently light and portable so that one man can disassemble, move 300 ft and reassemble in several hours. The 14 sprinkler heads are a typical jet rain spray pattern and each is rated to deliver 3.61 gpm at 40 psi over an area measuring 54 ft in diameter.A time clock and solenoid valve have also been designed to start and stop the irrigation automatically at designated times.

7.3.6 Electrical Supply 220/110 voltage service has been supplied to the demonstration site for power to operate the blower, control lighting and other mensurative equipment and appurtenances.

7.4 Construction Summary The refuse used to fill the aeration cells is weighed at the gate house to determine the weight of refuse placed in each test cell. The cells are surveyed periodically and the volumes are calculated. As the cells are filled landfill equipment mixes and compacts the refuse. Definitive compaction densities will be calculated, settlement plates and bench marks installed and subsequent volume reduction and settlement recorded.

7.5 Mensurative Equipment After completing cell construction, access holes will be bored and test equipment installed to measure internal and external temperatures and humidity, moisture, differential and total cell settlement and collection of gas and leach samples. Plate V illustrates placement of the equipment. Other sampling conduits and probes are being installed during placement of the refuse. Climatological data is compiled to relate cell activity with external climatic conditions. Other surface test equipment is maintained in a portable field shelter located at the site.

8.0 PRELIMINARY COST ANALYSIS

8.1 General A preliminary cost analysis of several alternative methods of processing and disposing of 250 tons per day of domestic refuse was made. These were incineration, normal sanitary landfill, composting, and controlled aeration for both biological and in situ incineration. The basis for this evaluation was a tributary population of 100,000, approximately the size of the Santa Clara sanitary landfill service area. The per capita production was estimated to be 5.0 lb per day. In each case the composition of raw refuse was assumed to approximate 50 percent volatile matter, 25 percent inerts, and 25 percent moisture on a wet weight basis (2/3 volatiles and 1/3 inerts on a dry weight basis).

Appendix 4 presents the additional assumptions, references and calculations involved in this analysis. Several basic factors requiring further detailed studies are the in-place density of compacted refuse, the length of time required for decomposition of refuse, the value of reclaimed land and the degree of stability of the completed fill. It is anticipated that the landfill resulting from external or in situ incineration residue may be compacted to provide reasonably stable foundations for certain higher type uses, such as industrial, commercial or residential sites. In contrast, in addition to creating other nuisances and problems, a normal completed sanitary landfill constructed with unoxidized refuse or even compost produces gases and settles for many years. This makes the land hazardous for unrestricted building sites.

8.2 Preliminary Results Table 10 summarizes the results of this preliminary evaluation. The total per ton processing and disposal cost for the case study was projected to be $8.53 for incineration; $1.50 for normal sanitary landfill; $4.29 for composting; and $1.78 for controlled aeration, disregarding the ultimate value of the completed landfill. It should be noted that this preliminary analysis for the particular case study may be optimistic. Refinements will be made after operating results of the aeration and compaction demonstrations become available. Each particular application must, of course, be separately evaluated.

9.0 PILOT STUDIES

9.1 Objectives Preparatory to initiating the large scale field demonstration program for the rapid oxidation and stabilization of solid wastes, certain pilot plant facilities were established at the project engineer's laboratory to demonstrate improved volume reduction. The concepts employed included (1) underground incineration; (2) rapid biological oxidation by controlled aeration, moisture application, heating and natural thermophilic heat generation; (3) improvement of odor and particulate filtration and adsorption by varying the soil cover in terms of depth, type, moisture content and charcoal admixture; and (4) other chemical and physical methods for accelerated degradation.

9.2 Biological Test Cylinder Descriptions Cylinders 1,2, and 3

9.2.1 Construction Plates VII and VIII schematically illustrate the pilot plant facilities. The Cylinders were designed to simulate the field conditions of large-scale aerobic cells within practical tolerances. Cylinders 1, 2, and 3 were constructed of 24 in diameter asphalt dipped steel pipes. The bottoms were sealed with a three in course of compacted earth and mastic. Cylinders 1 and 2 contained air distribution piping embedded in a 6 in course of gravel; Cylinder 3 was naturally aerated; Cylinders 4 and 5 which were used solely for the underground incineration studies, are described in Section 9.3.

The initial depths, weights, moisture and organic contents of refuse within these pilot facilities are noted on Table 5 and Plate VIII. The refuse composition replicated that typically observed at the Santa Clara Landfill and averaged 72 percent paper, 18 percent yard trimmings and other vegetation, 8 percent inert and 2 percent garbage by dry weight.

The moisture content ranged from 21 to 63 percent (dry weight) and the density averaged 313 lb/cu yd (dry weight).

The two types of soil cover used consisted of (1) silty sand and top soil, (2) beach sand, Plate VIII indicates the location of typical gas sampling, temperature and moisture probes.

9.2.2 Operation As indicated, Cylinders 1, 2, and 3 were used to study biological decomposition under varying parameters. Cylinders 1 and 2 were mechnically aerated, while Cylinder 3 was used to establish control parameters.

The operating practices and equipment employed are briefly described in Appendix 5, "Summary of Test Procedures".

The cylinders were periodically compacted to simulate natural settlement of a landfill and reduce sidewall boundary adhesion. The settlement was measured and recorded in Table I and Plate IX.

Gas samples taken from the soil cover as well as from the refuse were analyzed at predetermined intervals to determine the type of decomposition. Results of these analyses are tabulated in Table 2 and plotted on Plates XIII through XVII.

Cylinders 1 and 2 were operated at different original moisture contents, 63 percent compared to 29 percent, and at different rates of water addition to evaluate the relationships between biochemical degradation of refuse and its moisture content. Table 4 is a tabulation of the rates of water addition in relation to the elapsed time.

As the rate of excess aeration increased, the temperature of the refuse approached the air supply temperature and deviated from the ambient temperature and vice versa. Temperatures of the refuse, soil cover, air supply and ambient were continuously recorded and are shown in Table 3. Temperatures are plotted on Plates XXII through XXIV.

9.2.3 Results There was more biochemical decomposition in Cylinder 1 than in Cylinder 2, as indicated by the higher temperatures and greater volume reduction. Since organisms can obtain their nutrients only in fluid form through their cell walls, and since there is better utilization of oxygen in moist than in wet refuse, the results indicate that the original moisture content in Cylinder 2 was less effective than for Cylinder 1. The addition of water thereafter saturated parts of the refuse,and this may have affected the uniform flow of fresh air.

Because of cylinder boundary effects and excess air, the temperatures of the refuse were below the level desired for optimum meso- or thermophilic decomposition. However, based on other tests, it is expected that the temperature in the field demonstration will be easily maintained at 120 - 160°F, with accompanying accelerated biological activity.

In aerobic digestion, the higher temperatures are achieved by the activity of thermophilic micro-organisms. The optimum temperature for growth of these organisms is 122°F. The temperatures recorded in the cylinders indicated that a process of fermentation involving mesophilic organisms had occurred.

9.3 Controlled Underground Incineration - Cylinders 4 and 5

9.3.1 Test Cylinder Construction To study this advanced concept of volume reduction, two 55 gal steel drums, 22.5 in diameter and 35 in high, were constructed as illustrated on Plate XXVI. The cylinders were coated to minimize corrosion.

A 3 in layer of soil at the bottom of the cylinders provided a bedding for perforated spiral copper tubing that distributed the blower air. Immediately above this, a 7 in layer of gravel was placed. The burners, which initiated combustion in the test cylinders,were placed in the

gravel media to avoid direct contact with the refuse.

The initial depths of compacted refuse, weights, moisture contents, percentage organic matter and densities are tabulated in Tables 1, 5, and 7. The average depth of refuse was 11 in, and the composition was 74 percent paper and rags, 16 percent grass and yard trimmings, 2 percent garbage, and 8 percent inerts, based on dry weight. The initial density averaged 380 lbs/cu yd with a moisture content of 36 percent (dry weight). The refuse was covered with a 1 ft blanket of sandy soil for nuisance prevention, odor control and heat retention.

9.3.2 Operation Thirteen test runs were made over a five month period. Parameters such as rate of aeration, admixture of petroleum products, heating, drying, and refuse composition and density were studied. The tests evaluated the following factors: underground incineration, predrying, smoke filtration, and odor control. Detailed test procedures are described in Appendix 5.

The controlled variables were refuse density, moisture content, and rate of aeration. The results of the two test series were compared to establish a relationship between time, combustion efficiency, aeration rate and refuse density.

The original pioneer shakedown tests in development of the process were only partially successful because of excessive refuse moisture content from heavy rains, low air flow, and erratic burner or blower operation.

Refuse settlement during the drying and burning process was aided at predetermined intervals by dropping a 200 lb weight a distance of 6 in, twenty-five times.

Gas samples were periodically taken from two locations: (1) the soil layer 6 in from the cylinder top, and (2) the refuse layer 19 to

20 in from the cylinder top. The first probe was designed to determine the effectiveness of soil as a smoke, odor, and gas filtration medium; the second measured the gases generated by refuse incineration. See Plates XVIII through XXI for gas composition.

A chromatograph and Orsat Gas Analyzer were used to analyze the gas samples for CO_2, O_2, N_2, CH_4, and CO. Since this phase of the experiment was concerned with accelerated decomposition, the percentages of CO_2, CO and O_2 were of primary interest; particular attention was paid to the amount of oxygen necessary to bring about complete combustion in an optimum time period.

Temperature variations, gas composition, and settlement rate were tabulated to compare the following relationships:

a. O_2 quantities versus settlement rate, density and weight reduction.

b. Temperatures versus settlement rate, density and weight reduction.

c. Temperatures versus O_2 consumption and CO_2 production.

d. Gas composition during three separate phases of underground refuse incineration.

   1. Drying
   2. Rapid burning
   3. Residual burning

The changes in relative moisture of the soil cover was measured to determine the effects on odors, surface-cracks, gas composition and related health or safety factors. The comparative volatile organic contents provided an index for evaluating the completeness of incineration.

9.3.3 Results The total incineration process cycle involved some 8 days: pre-drying (3 days); rapid burning (3 days); and residual burning (2 days). During the drying phase, the refuse and soil exhibited some settlement, averaging 4 percent per day; O_2 consumption and CO_2 production were negligible. The principle results of drying were to improve combustion and reduce smoke and odors during rapid burning.

The rapid burning phase began when temperatures reached the ignition point of approximately 450°F adjacent to the burner element. The burning face then advanced through the refuse at a rate inversely proportional to the density of the refuse and directly proportional to the amount of oxygen (air) supply. The inter-relationship of settlement or volume reduction per day with quantity of air supply and initial refuse density is illustrated on Plate XXV.

Very little odor or smoke occurred when the rate of aeration was adequate; i.e., when there was more than 500 percent excess air. At lesser rates of aeration, CO_2 production decreased, CO production increased and smoke and odors began to appear, indicating partial combustion.

Most of the refuse was either paper or plant trimmings. When dry, these materials ignited rather easily and burned at a generally uniform rate during the rapid incineration phase. There were, however, some materials such as thick (3-4 in diameter) wood and plastics which continued to burn for longer durations. This residual burning accounted for small amounts of settlement during the later stages of each test and averaged 2 percent per day. The consumption of O_2 and production of CO_2 decreased considerably, but these quantities were still detectable.

Several tests achieved almost total volume reduction because of refuse slag and earth fusion. Other tests achieved the less dramatic volume reductions normally associated with partially burned refuse and ashes. Photograph 24 shows residue from one of these tests.

As might be expected, moisture content had a pronounced effect on the rate of burning and settlement. Pre-dried refuse burned more rapidly than damp refuse, and excessively wet refuse exhibited incomplete combustion and only partial volume reduction.

Reduction of odors was achieved by adding moisture to the soil filter at the appropriate time. A layer of activated charcoal was also effective for this purpose. The possible use of an enclosure such as a portable building or asbestos blanket for the collection of gases, in conjunction with a stack for their afterburning and dispersion in the atmosphere, is considered as a third alternative for future investigations.

The experimental data derived from this series of tests indicate that underground refuse incineration is technically feasible. However, before initiating large scale demonstrations, further pilot studies are required to define practical limitations and optimize various parameters such as odor control, rate of aeration, amount of pre-drying, temperatures, and mode of ignition. The second phase underground incineration tests are being financed as an in-house effort. Preliminary results of these later studies indicated that pre-drying and heating the refuse produced more satisfactory oxidation with less obnoxious odors and improved operational control and reliability.

A major advantage of underground incineration is the effective oxidation due to the high temperatures resulting from the insulating effects of the earth blankets and the long burning contact period with low air velocity and soil filtration which minimize air pollution.

9.4 Pulping Experiment

9.4.1 Purpose Pulping of paper and leaves was investigated to determine the feasibility of achieving greater compaction by breaking down these materials for thickening and landfill disposal while also allowing the use of water carriage collection systems.

9.4.2 Description Twenty 3 gr samples of paper and fourteen 3.5 gr samples of leaves were mixed with 425 ml of water each; the suspension was reduced to wet pulp in a mixer. The tests were conducted in two parts for each material. Initially, all parameters were held constant except the blender speed. In the second test, all parameters were held constant except initial water temperature.

9.4.3 Results Relationships of mixer blender speed and starting temperature to time are illustrated on Plate XXVII.

100 percent pulping of paper was achieved in a few seconds at all speeds and temperatures. There was only minimum improvement in pulping efficiency as mixer speeds were increased above 2400 rpm and/or as temperatures were increased above 70°F.

50 percent pulping of leaves occurred at speeds of 2400 rpm, and increased to 80 percent at 3600 rpm. Pulping did not improve at speeds in excess of 3600 rpm. Pulping efficiency was proportional to temperature up to 200°F.

An auxiliary test determined that the temperature of a pulped sample would drop from 200°F (ambient) in 45 seconds while being blended, thus providing a simple method for discharging wastes at normal temperature to sewers or other receiving systems.

In summary, it may be stated that pulping of paper offers good possibilities of becoming feasible with minimum process controls. Pulping of wood and leaves will require more time, energy and better control practices. It is expected that refuse solids may be concentrated in a practical disposal situation in a landfill or by some modification of existing sewerage facilities. Cellulose salvage from pulped refuse is being studied further.

10.0 SUPPLEMENTAL STUDIES

10.1 Other Operating Landfills For the first several months of the project, two preliminary and parallel phases of the work were carried out. One was a study of pertinent literature, the other, observation of other landfills to learn their operating procedures.

A bibliography of the more important writings on the subject of sanitary landfills and their operation appears in Section 11. The most important references are those concerned with the outstanding investigations carried out by the Solid Wastes Engineering Committee of the American Society of Civil Engineers, the American Public Works Association, the University of Southern California, and studies under the sponsorship of the California State Water Quality Control Board.

Operating landfills visited included all landfills in San Joaquin County, California; San Mateo and Alameda Counties in California, where land reclamation is being considered and/or practiced; various County and City of Los Angeles sites where deep canyon-type landfills are employed; Los Angeles County Sanitation Districts' Spadra Landfill in Walnut, California, where related PHS-sponsored research is being conducted; and several others within California, Illinois and Wisconsin.

10.2 Trucked Density and Unloading Studies During the time that refuse is being brought to the demonstration site in the municipal packers, a record is maintained of the characteristics of each load and truck. From this information, a tabulation of the computed trucked density can be prepared.

Time and motion studies will be conducted to find out how long it takes to weigh and unload various stake trucks and compactor type vehicles.

10.3 Normal City Collection and Disposal Practices During the course of this demonstration, the City's operating practices have been studied. The City employs one-man collection vehicles and the economies achieved

utilizing one-man collection have permitted the City to establish and equip the landfill site.

The landfill site is relatively free of litter, and refuse is regularly covered to maintain sanitary conditions. The City's efficient operation, well-maintained equipment, and thorough supervision encourage proper collection and disposal practices.

10.4 Ultimate Land Use In January 1966, a preliminary master plan for reclaiming the completed landfill for higher purposes was developed. To a limited extent, clean earth available from the cut and cover operations has been filled in areas designated for building sites and access roads with the normal sanitary landfill and demonstration areas set aside for parking and other non-structural uses. However, the Santa Clara City Council has not fully authorized the development of clean earthen fill areas, and the master plan is not being fully implemented to allow maximum refuse disposal volume.

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TABLE 1

TEST CYLINDER SHRINKAGE DATA

CYLINDER 1					CYLINDER 2				
Date	Time Elapsed Days	Settlement* In	Volume Reduction %	Remarks	Date	Time Elapsed Days	Settlement* In	Volume Reduction %	Remarks
1966				Refuse Depth=35½ in	1967				
12/24	0			Soil Cover =30½ in	1/6	0			Refuse Depth = 41½ in
					1/10	4	1-3/4	4	Soil Cover = 30 in
1967					1/18	12	3	7	
1/3	10	2	6		1/25	19	3	7	
1/4	11	2-1/4	6		1/31	25	3	7	
1/12	19	2-1/2	7		2/7	32	3-1/2	8	
1/18	25	3	8		2/8	33	4	10	
1/25	32	7-3/4	22		2/14	39	4	10	
1/31	38	8	23		2/22	47	4	10	
2/7	45	10-1/2	30		2/27	52	4	10	
2/8	46	10-1/2	30		3/2	55	4	10	
2/14	52	11	31		3/6	59	4-1/4	10	
2/22	60	12-1/4	35		3/20	73	4-1/4	10	
2/27	65	13	36		3/21	74	4-3/4	11	
3/2	68	16	45	Removed soil blanket & re-covered	3/27	79	5	12	
					4/5	88	5	12	
3/6	72	16	45		4/14	97	5-3/4	14	
3/20	86	17-1/2	49		5/1	114	6-1/4	15	
3/21	87	18-1/2	54		5/12	125	7	17	
3/26	92	18-1/2	54						
4/14	111	19	54						
5/1	128	19-1/2	55						
5/12	139	20	56						

* - Settlement recorded after compaction with 200 lb. weight dropping 6 in, 25 times.

TABLE 1 (Continued)

TEST CYLINDER SHRINKAGE DATA

CYLINDER 3					CYLINDER 4				
Date	Time Elapsed Days	Settlement* In.	Volume Reduction %	Remarks	Date	Time Elapsed Days	Settlement* In	Volume Reduction %	Remarks
1967				Refuse depth = 50 in	Soil cover = 12 in Test a				Refuse depth = 12 in
1/6	0			Soil cover = 19 in	1966				
1/18	12	4-1/4	8		12/31	0			Aeration & Burner started
1/25	19	6	12		1967				
1/31	25	6	12		1/3	4	2	17	Local burning in
2/7	32	6	12		1/4	5	2-1/2	21	vicinity of burner
2/8	33	6	12		1/10	11	3-1/2	29	" " "
2/14	39	6	12		Soil cover = 12 in Test b				Refuse depth = 12 in
2/22	47	6-1/2	13		1967				
2/27	52	7-3/8	15		1/14	0			Aeration Started & Burner on
3/2	55	7-3/8	15		1/18	4	1-3/4	15	
3/6	59	8-1/2	17		1/25	11	3-1/2	29	Rainfall inter-
3/20	73	8-1/2	17						fered with test.
3/21	74	9-3/8	19		Soil cover = 10 in Test c				Refuse depth = 12 in
3/27	79	10	20		1967				
4/5	88	10-1/2	21		1/26	0			Aeration Started
4/14	97	11-1/4	22		2/7	12	3-1/2	29	Pre-dried Refuse
5/1	114	11-1/4	22		2/8	13	3-1/2	29	Burner on
5/12	125	11-1/2	23.0		Soil cover = 12 in Test d				Refuse depth = 9 in
					1967				Aeration started 2/20
					2/20	0			Excess air & Petroleum
					2/24	4	5	56	inducing controlled burning
					2/27	7	6	67	" " "
					3/2	10	7	80	" " "
					3/8	16	7-1/4	81	" " "
									Burner on 2/22

TABLE 1 (Continued)

TEST CYLINDER SHRINKAGE DATA

CYLINDER 4					CYLINDER 4				
Date	Time Elapsed Days	Settlement* In	Volume Reduction %	Remarks	Date	Time Elapsed Days	Settlement* In	Volume Reduction %	Remarks
Test d continued					Soil cover = 11 in Test g				Refuse depth - 8 in
3/21	29	7-1/4	81		5/4	0			Aeration Started
3/27	34	7-3/8	83		5/8	4	0		Burner on
4/5	43	7-1/2	84		5/9	5	1	13	
Soil cover = 11 in Test e				Refuse depth = 12 in	5/10	6	1-1/2	19	High Refuse Density
1967					5/11	7	4-1/2	56	700 lb/cu yd
4/8	0			Aeration started	5/12	8	5-1/2	69	
4/11	3	1	8	Burner on	5/15	11	7-3/4	97	
4/13	5	1-1/2	12		5/16	12	7-3/4	97	
4/14	6	2-1/4	19		Soil cover = 11 in Test h				Refuse depth = 11 in
4/15	7	3-1/4	27		1967				
4/18	10	3-1/2	29	Rainfall interfered	5/19	0			Aeration Started
4/20	12	3-3/4	31	with test	5/22	3	0		Burner on
4/21	13	4	33		5/23	4	2-1/2	23	
4/25	17	4-1/4	35		5/24	5	7	64	Refuse dried
Soil cover = 11in Test f				Refuse depth = 12 in	5/25	6	8-1/2	77.4	
4/27	0			Aeration started	5/26	7	10	91	
4/28	1	2	17	Burner on	5/27	8	11	100	Soil cover settled
5/1	4	7-1/2	63		5/29	10	11	100	
5/2	5	7-3/4	65						

TABLE 1 (Continued)

TEST CYLINDER SHRINKAGE DATA

CYLINDER 5

Date	Time Elapsed Days	Settlement* In	Volume Reduction %	Remarks
Soil cover = 11-1/2 in Test a				**Refuse depth = 12 in**
1967 3/21	0			Aeration started
3/24	3	2	17	Burner on
3/25	4	9-3/4	81	Burner off substantial smoke continued
3/27	6	12-1/2	100	Soil Cover Settled
Soil cover = 13 in Test b				**Refuse depth = 10 in**
4/11	0			Aeration started
4/13	2	2-3/4	27	Burner on
4/14	3	7	70	
4/15	4	7-1/4	72	
4/18	7	7-1/4	72	
4/20	9	7-1/4	72	Charcoal added to
4/25	14	7-1/2	75	Soil cover
Soil cover = 11 in Test c				**Refuse depth = 12 in**
4/27	0			Aeration std. 4/27
4/28	1	1	8	Burner on 4/28
5/1	4	8	67	Kerosene admixed
5/2	5	8-1/4	69	with gravel
5/4	7	9	75	

CYLINDER 5

Date	Time Elapsed Days	Settlement* In	Volume Reduction %	Remarks
Soil cover = 11 in Test d				**Refuse depth = 12 in**
5/5	0			Aeration started
5/9	4	6	50	Burner on 5/8
5/10	5	6	50	
5/11	6	9-1/2	79	
5/12	7	11	92	
5/15	10	12	100	Soil Cover
5/16	11	12	100	Settled
Soil cover = 10 in Test e				**Refuse depth = 12 in**
5/19	0			Aeration started
5/22	3	0		Burner on
5/23	4	2-1/4	19	
5/24	5	6-1/2	54	
5/25	6	6-1/2	54	No Aeration
5/26	7	8	67	Re-Aerated
5/27	8	11	92	
5/29	10	12	100	Soil Cover hardened and a portion collapsed, forming a cavity.

TABLE 2

GAS COMPOSITION IN TEST CYLINDER 1

Date	Time Elapsed Days	Percent Composition by Volume of Gases Drawn from Sampling Probes Placed at Indicated Depth Below Top of Initial Soil Cover										Remarks
		Probe 1 at 7 in					Probe 2 at 17 in					
		CO_2	H_2	O_2	N_2	CH_4	CO_2	H_2	O_2	N_2	CH_4	
1966												
12/24	0			21.0	79.0				19.9	80.1		
12/27	3			20.8	79.2				20.3	79.7		
12/28	5											
12/31	7			19.8	80.2				17.2	82.8		
1967												
1/3	10			19.8	80.2				19.8	80.2		
1/4	11			20.6	79.4				19.2	80.8		
1/5	12			19.6	80.4				19.9	80.1		
1/12	19			20.5	79.5				20.5	79.5		
1/19	26			20.0	80.0							Probe 1 exposed to atmosphere on 1/25
1/27	34								20.6	79.4		Lost gas analysis of Probe 2
2/14	52						Tr		20.4	79.6		Probe 2 exposed to atmosphere
2/22	60						0.2		19.6	80.2		on 3/20
		Probe 4A at 58in										
1967												Installed Probe 4A on 3/19
3/20	86	0.3		20.1	79.6							
3/21	87	1.0		19.0	80.0							
3/21	87	1.8		19.2								
3/31	97	0.2		21.2	78.6							
4/21	118	0.0		20.0	80.0							Orsat Analysis
4/21	118	0.9		19.3								
4/28	125	0.0		20.6	79.4							
5/5	132	0.0		21.2	78.8							
5/12	139	0.1		20.4	79.5							
5/26	153	0.1		20.9	79.0							

NOTE: Analysis by chromatograph except where otherwise noted.

TABLE 2 (Continued)

GAS COMPOSITION IN TEST CYLINDER 1

Date	Time Elapsed	Percent Composition by Volume of Gases Drawn from Sampling Probes Placed at Indicated Depth Below Top of Initial Soil Cover										Remarks
		Probe 3 at 25 in					Probe 4 at 38 in					
	Days	CO_2	H_2	O_2	N_2	CH_4	CO_2	H_2	O_2	N_2	CH_4	
1966												
12/24	0			20.6	79.4				18.0	82.0		
12/27	3			20.4	79.6				19.0	81.0		
12/28	5			20.4	79.6				18.8	81.2		
12/31	7			17.9	82.1				19.5	80.5		
1967												
1/3	10			18.9	81.1				18.5	81.5		
1/4	11			21.0	79.0				18.0	82.0		
1/5	12			19.2	80.8				18.5	81.5		
1/12	19			19.5	80.5				19.4	80.6		
1/19	26						0.2		11.7			Orsat Analysis
1/27	34			20.0	80.0				20.9	79.1		
2/3	41			21.2	78.8				20.8	79.2		
2/7	45			21.3	78.7							
2/9	47	0.2		20.5								Orsat Analysis
2/9	47	7.4		11.6								Orsat Analysis
2/14	52			20.2	79.8				21.0	79.0		
2/20	58						2.0		17.0	81.0		
2/22	60	Tr		20.8	79.2		1.4		17.8	80.8		
2/27	65						10.2		7.1	82.7		
3/4	70						0.3		20.0	79.7		
3/6	72											
3/15	81								20.9	79.1		
3/20	86						0.1		20.2	79.7		
3/21	87						1.6		19.3	79.1		
3/21	87						8.0		13.5	78.5		Orsat Analysis
3/31	97								21.0	79.0		
5/26	153						Tr		20.5	79.5		

TABLE 2 (Continued)

GAS COMPOSITION IN TEST CYLINDER 2

Date	Time Elapsed Days	Percent Composition by Volume of Gases Drawn from Sampling Probes Placed at Indicated Depth Below Top of Initial Soil Cover										Remarks
		Probe 5 at 12 in					Probe 6 at 21 in					
		CO_2	H_2	O_2	N_2	CH_4	CO_2	H_2	O_2	N_2	CH_4	
1967												
1/12	6			20.8	79.2							
1/27	21			20.0	80.0				20.2	79.8		
2/3	28						1.3		19.7	79.0		
2/14	39	0.7		20.8	78.5				20.8	79.2		
2/24	47	0.8		20.6	78.6		0.9		19.7	79.4		No gas samples taken from these probes after 2/22

TABLE 2 (Continued)

GAS COMPOSITION IN TEST CYLINDER 2

Date	Time Elapsed	Percent Composition by Volume of Gases Drawn from Sampling Probes Placed at Indicated Depth Below Top of Initial Soil Cover										Remarks
		Probe 7 at 30 in					Probe 8 at 42 in					
	Days	CO_2	H_2	O_2	N_2	CH_4	CO_2	H_2	O_2	N_2	CH_4	
1967												
1/12	6								20.8	79.2		
1/19	13	0.5		11.7								Orsat Analysis
1/23	17			19.9	80.1				17.6	82.4		
1/27	21	Tr		20.3	79.7		0.5		19.0	80.5		
2/3	28	1.9		19.8	78.3							
2/7	32	4.6		15.5	79.5							
2/9	34	3.6		16.8								Orsat Analysis
2/9	34	2.0		18.6								Orsat Analysis
2/14	39			20.0	80.0							
2/20	45						1.0		19.8	79.2		
2/22	47	1.4		19.7	78.9		0.9		19.8	79.3		
3/4	57			19.5	80.5				20.6	79.4		
3/6	59											
3/15	68						3.5		17.4	79.1		
3/20	73	1.6		18.7	79.6		1.2		19.3	79.5		
3/21	74	1.6		18.0	80.4		0.5		20.2	79.3		
3/21	74	2.9		17.7	79.4		2.1		18.7	79.2		
3/31	84	4.0		16.0	80.0		2.0		17.5	80.5		
4/18	102						3.9		14.9	81.2		
5/2	126						0.2		20.8	79.0		
5/26	140	0.3		20.2	79.5		0.2		20.3	79.5		

TABLE 2 (Continued)

GAS COMPOSITION IN TEST CYLINDER 3

Date	Time Elapsed	Percent Composition by Volume of Gases Drawn from Sampling Probes Placed at Indicated Depth Below Top of Initial Soil Cover										Remarks
		Probe 11 at 25 in					Probe 12 at 37 in					
	Days	CO_2	H_2	O_2	N_2	CH_4	CO_2	H_2	O_2	N_2	CH_4	
1967												
1/18	12			20.2	79.8							
1/19	13	8.0		7.2								
1/23	17											
1/26	20	14.1		6.9	79.0							
1/27	21	13.3		6.7	80.0							
2/3	28	Tr		21.0	79.0							
2/14	39	0.3		20.4	79.5							
2/20	45											
2/22	47	12.9		9.7	77.4							
3/2	55											
3/6	59			21.0	77.0							Orsat Analysis
3/15	68	10.7		5.9	83.4							
3/20	73	14.2		9.5	76.5		18.8		5.7	75.5		
3/21	74	12.9		11.6	75.5		18.0		3.5	78.5		
3/21	74	15.2					18.6					
3/31	84	14.2		6.3	79.5		11.4		9.4	79.2		Orsat Analysis
4/18	102						7.2		7.2	85.6		
4/21	105						11.0		8.4			Orsat Analysis
5/5	119											Insulated Cylinder
5/9	123						16.6		4.0			
5/12	126						17.8		4.0	78.2		Orsat Analysis
5/26	140	9.3		9.7	81.0		16.1		6.1	77.8		

TABLE 2 (Continued)

GAS COMPOSITION IN TEST CYLINDER 4

Test	Date	Time Elapsed	Percent Composition by Volume of Gases Drawn from Sampling Probes Placed at Indicated Depth Below Top of Initial Soil Cover										Remarks
			Probe 13 in sand cover					Probe 14 at 19 in					
		Days	CO_2	O_2	N_2	CH_4	CO	CO_2	O_2	N_2	CH_4	CO	
4a	1967												
	1/3	4	0.4	18.6	76.7	0.9	3.4	0.2	14.3	70.5	3.0	12.0	
	1/4	5		18.7	81.3				12.2	86.0	0.1	1.7	
	1/5	6							12.9	83.0	2.1	2 9	
	1/12	13							20.0	80.0			
4b	1/18	4		21.0	79.0				21.0	79.0			
	1/19	5							11.8				Orsat Analysis
	1/23	9		21.0	79.0								
4c	1/27	0		19.5	80.5			6.6	8.9	84.5			Before Aeration
	1/27	0		20.2	79.8			2.5	18.4	79.1	Tr	Tr	During Burning
	1/27	0		20.1	79.9			25.7	12.8	51.5	4.0	6.0	After Burning
	2/3	6		20.7	79.3			0.2	20.6	79.0	.1	0.13	
	2/7	10						2.9	18.8	78.0		0.3	During Burning
	2/9	12						9.8	9.5				Orsat Analysis
													During Burning
	2/13	16											Before Take-Down, after Burning
4d	2/22	2	1.2	19.3	79.1		0.4	0.1	20.8	79.1			During Burning
	2/24	4	1.6	18.8	79.5		0.1	0.1	20.4	79.5			
	3/1	8						0.1	20.6	79.3			
	3/4	11	0.1	21.0	78.9								After Combustion
	3/6	13		20.0	80.0								
	3/19	22						0.1	20.5	29.4			
4e	4/18	10							20.4	79.6			
	4/21	13							19.3	80.6	0.1		During Burning & Rain

TABLE 2 (Continued)

GAS COMPOSITION IN TEST CYLINDER 4

Test	Date	Time Elapsed	Percent Composition by Volume of Gases Drawn from Sampling Probes Placed at Indicated Depth Below Top of Initial Soil Cover										Remarks
			Probe 14 at 19 in										
		Days	CO_2	O_2	N_2	CH_4	CO						
4f	1967												
	4/28	1		20.8	79.0	0.2							
	5/1	4		21.0	79.0								Taken at 11 A.M.
	5/1	4		20.7	79.3								Taken at 11 A.M.
	5/21	5		21.0	79.0								12:45 P.M. when air turned off
	5/21	5		20.2	79.8								3:45 P.M.
4g	5/8	4		20.6	79.4								Turned air on before turning Burner on
	5/8	4	0.1	21.0	78.8	0.1							During burning
	5/12	8	0.1	20.5	79.4								Burner on
	5/15	11	1.4	19.3	79.3								Burner on
4h	5/19	0	0.7	19.5	79.8	Tr							Before air and burner on
	5/22	3	9.2	13.5	77.3								Before air and burner on
	5/22	3		20.6	79.4								After air on
	5/22	3	0.3	20.5	79.2								After burning for 5½ hours
	5/24	5	7.4	14.9	76.0	Tr	1.7						
	5/26	7	3.4	17.6	79.0		Tr						
	5/31	12	1.3	19.2	79.5								

TABLE 2 (Continued)

GAS COMPOSITION IN TEST CYLINDER 5

Test	Date	Time Elapsed	Percent Composition by Volume or Gases Drawn from Sampling Probes Placed at Indicated Depth Below Top of Initial Soil Cover										Remarks
			Probe 15 in sand cover					Probe 16 at 20 in					
		Days	CO_2	O_2	N_2	CH_4	CO	CO_2	O_2	N_2	CH_4	CO	
5a	1967												
	3/25	4	Tr.	21.0	72.6	0.2	6.2	0.8	6.6	69.0	2.3	21.3	After extensive burning
	3/25	4		7.8	83.7	2.1	6.4		10.7	89.3			Air supply off
	3/25	4		12.6	79.3	3.7	4.4		20.8	77.4	0.1	1.7	Air supply on
	3/27	6		20.7	79.3				20.2	79.8			Air supply off
	3/27	6		20.8	79.2				21.3	78.7			
5b	4/18	7							20.3	79.7			
	4/21	10							13.6	86.4			During burning
5c	4/28	1							20.5	79.5			
	5/1	4						0.2	20.2	79.6			
	5/1	4						0.2	20.5	79.3			
	5/2	5						1.9	15.8	82.1	0.2		12:45 P.M. with air supply off
	5/2	5						10.2	0.8	88.5	0.1	0.4	3:45 P.M.
5d	5/8	3							21.0	79.0			Prior to burning
	5/8	3						0.3	21.0	78.5	0.3		During burning
	5/12	7						Tr	20.8	79.2			Burner on
	5/15	10							21.1	78.9			Burner on
5e	5/19	0						Tr.	18.0	81.8	Tr.		Before Aeration & burning
	5/22	3							21.0	79.0			Prior to burning
	5/22	3						0.4	21.0	78.6			Burner on 5½ hours
	5/24	5						34.4	1.8	58.8	1.9	3.1	
	5/26	7						6.4	14.4	78.0	0	1.2	
	5/31	12						0	21.3	78.7	0	0	

TABLE 3

TEMPERATURE AND RELATIVE HUMIDITY
IN CYLINDER 1

Date	Time Elapsed Days	Ambient Humidity %	Temperature °F								
			Ambient			Air Supply	(1) Depth of Probe,				
			Max	Min	Avg		7"	17"	25"	38"	58"
(1966)											
12-24	0	42	71	45	58	63	73	70	78	75	
12-27	3	45	64	35	50	75	79	72	77	79	
12-28	4	45	62	37	50	72	80	74	80	86	
12-29	5	32	66	39	53	69	75	70	77	83	
12-30	6	43	67	45	56	66	75	70	77	91	
12-31	7	38	66	41	54	65	72	73	80	96	
(1967)											
1-3	10	37	73	42	58	69	75	72	81	97	
1-4	11	37	74	47	61	63	79	76	84	95	
1-5	12	52	66	47	57	68	79	75	82	90	
1-6	13	43	65	41	53	70	74	69	76	80	
1-11	18	38	82	49	66	109	83	78	84	79	
1-12	19	44	74	49	62	105	83	76	79	72	
1-18	25	49	76	40	58	101	75	68	72	67	
1-20	27		62	44	53	96					
1-23	30	64	60	45	53	96	79	68	75	68	
1-25	32	64	53	45	54	97	78	64	71	72	
1-26	33	55	70	42	56	99		69	74	68	
1-31	38	57	64	50	57	100	76	68	73	69	
2-1	39	61	64	47	56	99	78	69	74	70	
2-2	40	42	74	44	59	102	89	70	78	74	
2-6	44		72	47	59	102	94	78	88	97	
2-8	46		79	48	64	107		75	80	85	
2-9	47	48	70	44	57	100		75	81	80	
2-14	52	55	64	53	54	97		73	79	77	
2-20	58		69	42	56	99		73	78	79	
2-22	60	25	78	39	59	102		75	80	77	
2-27	65	48	81	46	64	107		71	75	67	
3-2	68	53	75	46	61	104		75	89	79	
3-15	81	54	72	48	60	103		68	75	71	
3-17	83	60	69	56	63	106		95	84	79	
3-20	86	57	69	50	60	103			84	75	76
3-27	93	55	78	54	66	90			83	71	33
3-29	95	42	70	52	61				84	73	73
3-31	97	55	62	50	56	88			86	70	71
4-5	102	56	65	48	57	92			78	69	68
4-7	104	70	65	53	59	85			81	69	72
4-10	107	56	72	47	60	90			79	68	73
4-12	109	52	66	48	57	100			81	71	69
4-14	111	60	67	57	62	78			86	68	73
4-17	114	56	69	50	60	76			89	72	73
4-19	116	74	54	46	50	72			78	60	66
4-21	118	77	59	48	54	69			82	64	67

(1) Depth of Probes is depth below original ground surface.

TABLE 3

TEMPERATURE AND RELATIVE HUMIDITY
IN CYLINDER 1

Date	Time Elapsed Days	Ambient Humidity %	Temperature °F								
			Ambient			Air Supply			Depth of Probe,		
			Max	Min	Avg				25"	38"	58"
4-24	121	55	66	50	58	76			80	70	71
4-28	125								87	68	75
5-1	128	27	78	52	65	92			85	75	74
5/5	132	47	67	57	62	79			86	71	75
5/8	135	51	82	44	63	70			92	77	78
5/9	136	60	70	62	66	72			84	69	77
5/10	137	47	73	61	67	72			85	69	75
5/12	139	42	76	61	68	72			91	71	76
5/15	142	30	103	64	83	105			100	89	86
5/17	144	62	85	68	77	84			93	81	87
5/22	149	56	82	61	71	82			89	78	80
5/24	151	37	85	69	77	94			85	76	79
5/26	153	49	74	70	72	84			83	73	78

TABLE 3 (Continued)

TEMPERATURE AND RELATIVE HUMIDITY
IN CYLINDER 2

Date	Time Elapsed Days	Ambient Humidity %	Temperature °F							
			Ambient			Air Supply	Depth of Probe			
			Max	Min	Avg		12"	21"	30"	42"
(1967)										
1-11	5	38	82	49	66	109	80	71	78	84
1-18	12	49	76	40	58	101	75	65	72	84
1-23	17	64	60	45	53	96	79	65	69	77
1-25	19	58	63	45	54	97	79	63	68	75
1-26	20	55	70	42	56	99	73	63	70	77
1-31	25	57	64	50	57	100	77	66	72	82
2-1	26	61	64	47	56	99	78	66	74	80
2-2	27	42	74	44	59	102	88	72	76	83
2-6	31		72	47	59	102	90	74	79	88
2-8	33		79	48	64	107	78	68	75	85
2-9	34	48	70	44	57	100	82	70	77	85
2-14	39	55	64	53	54	97	78	68	75	85
2-20	45		69	42	56	99	86	71	75	80
2-22	47	25	78	39	59	102	84	71	77	84
2-27	52	48	81	46	64	107	75	65	73	80
3-2	55	53	75	46	61	104	92	78	83	92
3-15	68	54	72	48	60	103	75	65	71	75
3-17	70	60	69	56	63	106	88	74	78	82
3-20	73	57	69	50	60	103	82	71	76	83
3-27	80	55	78	54	66	90	78	68	73	82
3-29	82	42	70	52	61		91	73	77	81
3-31	84	55	62	50	56	88	81	67	72	78
4-5	89	56	[illegible]	48	57	92	87	68	71	76
4-7	91	70	65	53	59	85	84	68	73	78
4-10	94	56	72	47	60	90	80	67	73	79
4-12	96	52	66	48	57	100	82	68	71	77
4-14	98	60	67	57	62	78	88	70	74	78
4-17	101	56	69	50	60	76	87	70	74	78
4-19	103	74	54	46	50	72	73	59	65	72
4-21	105	77	59	48	54	69	73	60	66	73
4-24	108	55	66	50	58	76	83	68	75	77
4-28	112		68	57	62		87	70	74	79
5-1	115	27	78	52	65	92	89	73	77	80
5-5	119	47	67	57	62		84	69	75	81
5-8	122	51	82	44	63	70	91	77	81	86
5-9	123	60	70	62	66	72	78	69	76	82
5-10	124	47	73	61	67	72	80	69	75	82
5-12	126	42	76	61	68	72	90	73	78	84
5-15	129	30	103	64	83	105	105	87	92	96
5-17	131	62	85	68	77	84	99	84	89	96
5-22	136	56	82	51	71	82	94	77	83	88
5-24	138	37	85	69	77	94	88	73	80	87
5-26	140	49	74	70	72	84	86	72	78	84

TABLE 3 (Continued)

TEMPERATURE AND RELATIVE HUMIDITY
IN CYLINDER 3

Date	Time Elapsed	Ambient Humidity	Temperature °F						Remarks
			Ambient			Air Supply	Depth		
	Days	%	Max	Min	Avg		25"	33"	
(1967)									
1-11	5	38	82	49	66		85		
1-18	12	49	76	40	58		77		
1-23	17	64	60	45	53		63		
1-25	19	58	63	45	54		68		
1-26	20	55	70	42	56		72		
1-31	25	57	64	50	57		75		
2-1	26	61	64	47	56		70		
2-2	27	42	74	44	59		79		
2-6	31		72	47	59		77		
2-8	33		79	48	64		78		
2-9	34	48	70	44	57		77		
2-14	39	55	64	53	54		72		
2-20	45		69	42	56		75		
2-22	47	25	78	39	59		84		
2-27	52	48	81	46	64		76		
3-2	55	53	75	46	61		77		
3-15	68	54	72	48	60		70		
3-17	70	60	69	56	63		80		
3-20	73	57	69	50	60		77	84	
3-27	80	55	78	54	66		78		
3-29	82	42	70	52	61		73		
3-31	84	55	62	50	56		71		
4-5	89	56	65	48	57		69		
4-7	91	70	65	53	59		68		
4-10	94	56	72	47	60		70		
4-12	96	52	66	48	57		71		
4-14	98	60	67	57	62		68		
4-17	101	56	69	50	60		71		
4-19	103	74	54	46	50		60	76	
4-21	105	77	59	48	54		64	69	
4-24	108	55	66	50	58		72	79	
4-28	112		68	57	62		69	71	
5-1	115	27	78	52	65	No mechanical aeration	79	89	
5-5	119	47	67	57	62		73	79	Insulated cylinder on 5/5 with 4 in aluminum faced fiberglass
5-8	122	51	82	44	63		74	111	
5-9	123	60	70	62	66		72	107	
5-10	124	47	73	61	67		69	104	
5-12	126	42	76	61	68		71	98	
5-15	129	30	103	64	83		82	109	
5-17	131	62	85	68	77		82	109	
5-22	136	56	82	71	71		75	107	
5-24	138	37	85	69	77		73	109	
5-26	140	49	74	70	72		73	100	

TABLE 3 (Continued)

TEMPERATURE AND RELATIVE HUMIDITY
IN CYLINDER 4

Date	Time Elapsed Days	Ambient Humidity %	Temperature °F Ambient Max	Ambient Min	Ambient Avg	Air Supply	Depth 6"	Depth 19"	Remarks
Test 4a (1966)									
12/30	0	43	67	45	56	99	66		
12/31 (1967)	1	38	66	41	54	97	62		Aeration & burner started
1/3	4	37	73	42	58	103	53		
1/4	5	37	74	47	61	106	108		
1/5	6	52	66	47	57	102	67		
1/11	11	38	82	49	66	111	62		
1/14	14								Taken down
Test 4b (1967)									Aeration & burner started on 1/15
1/23	8		80	45	53	96	62		
1/25	10		63	45	54	97			
Test 4c (1967)									
1/26	0								
1/27	1		75	47	61		64	72	No aeration
1/27	1		75	47	61	106	64	70	Aeration
1/27	1		75	47	61	106	74	220	Burner on
1/27	1		75	47	61	106	74	98	2 hrs. after burner
1/31	5	57	64	50	57	102	65	74	turned off
2/1	6	61	64	47	56	99	64	70	Burner off
2/2	7	42	74	44	59	102	74	220	Burner On
2/6	11		72	47	59	102		250+	Burner on 6.5 hrs.
2/6	11		72	47	59	102		250+	Burner on
2/9	14	48	70	44	57	100	84	250+	Burner on
Test 4d (1967)									
2/20	0		69	42	56	99			Aeration started
2/22	2	25	78	39	59	102	70	160	Burner on
2/23	3	45	80	45	63	106	95	250+	
2/24	4		72	49	61	104	111	130	
2/27	7	48	81	46	64	107	73	110	
3/2	10	53	75	46	61	104	90	152	
3/15	23	54	72	48	60	103	60	59	
3/17	25	60	69	56	63	106	72	71	
3/20	28	57	69	50	60	103	80	81	
3/27	35	55	78	54	66	90	69	81	
3/29	37	42	70	52	61	-	72	74	
3/31	39	55	62	50	56	88	65	63	
4/5	44	56	65	48	57	92	72	68	

TABLE 3 (Continued)

TEMPERATURE AND RELATIVE HUMIDITY
IN CYLINDER 4

Date	Time Elapsed Days	Ambient Humidity %	Temperature °F: Ambient Max	Ambient Min	Ambient Avg	Air Supply	Depth 6"	Depth 19"	Remarks
Test 4e (1967)									
4/8	0								Aeration started
4/10	2	56	72	47	60	90	72	66	Burner on
4/11	3		62	54	58	-	62	150	
4/12	4	52	66	48	57	100	80	76	
4/14	6	60	67	57	62	78	72	230	
4/15	7	55	65	54	60	80	80	370	
4/17	9	56	69	50	60	76	81	82	
4/19	11	74	54	46	50	72	56	56	
4/20	12	53	64	48	56		72	250	
4/21	13	77	59	48	54	69	61	130	
4/24	16	55	66	50	58	82	76	65	
Test 4f									Aeration started 4/27
4/28	1						82	140	Burner on
5/1	4	27	78	52	65	92	113	720	
5/2	5	39	76	57	66	86	93	97	
Test 4g									
5/5	1	47	67	57	62	79	72	78	
5/8	4	51	82	44	63	70			Burner on Time:
5/8	4	51	82	44	63	70	79	91	12:30
5/8	4	51	82	44	63	70	81	94	1:30
5/8	4	51	82	44	63	70	82	99	2:30
5/8	4	51	82	44	63	70	87	96	3:30
5/8	4	51	82	44	63	70	80	104	4:30
5/9	5	60	70	62	66	72	72	78	Burner off
							80	100	Burner on
5/10	6	47	73	61	67	72	98	116	Burner off
5/10									Burner on at 4:15 p.m.
5/11	7	47	74	60	67	72	100	142	Burner on 24 hrs.
5/12	8	42	76	61	68	72	115	174	Burner on 43 hrs.
5/15	11	30	103	64	83	105	140	550	Burner on 115 hrs.
Test 4h									
5/19	0								
5/22	3	56	82	61	71	82	94	92	Burner on 3 hrs.
5/22	3	56	82	61	71	82	83	120	Burner on 5 1/4 hrs.
5/23	4	52	91	68	79	84	87	150	Burner off
5/24	5	37	85	69	77	94	114	350	Burner on continuously
5/25	6	56	76	70	73	86	120	810	Burner on
5/26	7	49	74	70	72	84	115	350	Burner on
5/29	10	55	77	69	70	78	84	700	

TABLE 3 (Continued

TEMPERATURE AND RELATIVE HUMIDITY
IN CYLINDER 5

Date	Time Elapsed Days	Ambient Humidity %	Temperature °F: Ambient Max	Ambient Min	Ambient Avg	Air Supply	Depth 6"	Depth 20"	Remarks
Test 5a (1967)									
3/21	0								Aeration started
3/24	3	50	72	58	65	103	71	88	Burner on 6 hrs.
3/27	6	55	78	54	66	90	110	284	
Test 5b									
4/11	0								Aeration started
4/13	2	65	63	55	60	88	72	92	Burner on
4/14	3	60	67	57	62	78	93	110	
4/15	4	55	65	54	60	80	79	76	
4/17	6	56	69	50	60	70	82	70	
4/19	8	74	54	46	50	72	57	58	
4/21	10	77	59	48	54	69	60	64	Burner on
4/24	13	55	66	50	58	76	81	70	
Test 5c									
4/28	1						90	158	Burner on
5/1	4	27	78	52	65	92	144	200	
5/2	5	39	76	57	66	86	120	180	
5/4	7						118	660	
Test 5d									
5/8	0	47	67	57	62	79	80	80	
5/8	3	51	82	44	63	70			Burner on Time:
5/8	3	51	82	44	63	70	80	99	12:00
5/8	3	51	82	44	63	70	84	99	1:30
5/8	3	51	82	44	63	70	90	101	2:30
5/8	3	51	82	44	63	70	90	103	3:30
5/8	3	51	82	44	63	70	92	114	4:30
5/9	4	60	70	62	66	72	140	160	Burner on
							120	560	Burner on
5/10	5	47	73	61	67	72	140	230	Burner on
5/11	6	47	74	60	67	72	144	540	Burner on
5/12	7	42	76	61	68	72	130	830	Burner on for 21 hrs.
5/15	10	30	103	64	83	105	350	700	Burner on for 93 hrs.
Test 5e									
5/19	0								
5/22	3	56	82	61	71	82	80	94	Burner turned on
5/22	3	56	82	61	71	82	87	110	Burner on
5/23	4	52	91	68	80	94	110	186	continuously to
5/24	5	37	85	69	77	94	132	196	5/29
5/25	6	56	76	70	73	86	83	595	
5/26	7	49	74	70	72	84	120	690	
5/29	10	55	77	64	70	78	222	1000	

TABLE 4

WATER APPLIED TO CYLINDER 1

Date	Elapsed Time	Water Added		Rainfall[1]	Total Water Applied
	Days	Cal	In	In	In
(1966)					
12/24	0	1.40	0.71		0.71
12/27	3	1.50	0.77		1.48
12/29	5	0.50	0.26		1.74
12/30	6	0.50	0.26		2.00
12/31	7	0.50	0.26		2.26
(1967)					
1/4	11	0.50	0.26		2.52
1/9	16	0.50	0.26		2.78
1/13	20	2.00	1.02		3.80
1/14	21	1.00	0.51		4.31
1/22	29			1.60	5.91
1/23	30			0.22	6.13
1/24	31			1.20	7.33
1/25	32			0.25	7.58
1/31	38			9.27	7.85
2/3	41	24.00	14.28		22.13
2/9	47	10.00	5.10		27.23
2/22	60	4.00	2.04		29.27
2/25	63			0.15	29.42
3/8	74	4.00	2.04		31.46
3/10	76			Tr	
3/11	77			0.23	31.69
3/12	78			0.95	32.64
3/13	79	-1.87[2]	-0.95[2]	0.26	31.95
3/14	80			0.20	32.15
4/2	99			0.25	32.40
4/4	101			0.30	32.70
4/7	104			0.15	32.85
4/11	108			0.68	33.53
4/15	112			0.03	33.56
4/18	115			0.37	33.93
4/19	116			0.34	34.27
4/21	118			0.86	35.13
4/24	121			0.25	35.38
4/29	126			0.18	35.56
5/10	137			0.13	35.69

1. Rainfall based on U.S. Weather Bureau records for Culver City, California except May, 1967 which is recorded rainfall at U.C.L.A.

2. Denotes excess rainfall drained off.

TABLE 4 (Continued)

WATER APPLIED TO CYLINDER 2

	Elapsed Time	Water Added		Rainfall	Total Water Applied
Date	Days	Gal	In	In	In
(1967)					
1/9	3	2.00	1.02		1.02
1/10	4	4.00	2.04		3.06
1/13	7	10.00	5.10		8.16
1/14	8	9.00	4.59		12.75
1/22	16			1.60	14.35
1/23	17			0.22	14.57
1/24	18			1.20	15.77
1/25	19			0.25	16.02
1/31	25			0.27	16.29
2/3	28	12.00	6.12		22.41
2/9	34	10.00	5.10		27.51
2/22	47	4.00	2.04		29.55
2/25	50			0.15	29.70
3/8	61	4.00			31.74
3/10	63			Tr	
3/11	64			0.23	31.94
3/12	65			0.95	32.92
3/13	66			0.26	33.18
3/14	67			0.20	33.38
4/2	86			0.25	33.64
4/4	88			0.30	33.93
4/7	91			0.15	34.08
4/11	95			0.68	34.76
4/15	99			0.03	34.79
4/18	102			0.37	35.16
4/19	103			0.34	35.50
4/21	105			0.86	36.36
4/24	108			0.25	36.61
4/29	113			0.18	36.79
5/10	124			0.13	36.92

TABLE 4 (Continued)

WATER APPLIED TO CYLINDER 3

Date	Elapsed Time	Water Added		Rainfall[1]	Total Water Applied
	Days	Gal	In	In	In
(1967)					
1/22	16			1.60	1.60
1/23	17			0.22	1.82
1/24	18			1.20	3.02
1/25	19	-3.87[2]	-1.97[2]	0.25	1.30
1/31	25			0.27	1.57
2/25	50			0.15	1.72
3/10	63			Tc	
3/11	64			0.23	1.95
3/12	65			0.95	2.90
3/13	66			0.26	3.16
3/14	67			0.20	3.36
4/2	86			0.25	3.61
4/4	88			0.30	3.91
4/7	91			0.15	4.06
4/11	95			0.68	4.74
4/15	99			0.03	4.77
4/18	102			0.37	5.14
4/19	103			0.34	5.48
4/21	105			0.86	6.34
4/24	108			0.25	6.59
4/29	113			0.18	6.77
5/10	124			0.13	6.90

TABLE 4 (Continued)

WATER APPLIED TO CYLINDER 4

Date	Elapsed Time	Water Added		Rainfall[1]	Total Water Applied
	Days	Gal	In	In	In
Test 4a (1966)					
12/29		0.83	0.32		0.32
12/31	1	1.00	0.39		0.71
(1967)					
1/4	5	1.00	0.39		1.10
1/9	10	1.00	0.39		1.49
Test 4b (1967)					
1/22	7			1.60	1.60
1/23	8			0.22	1.82
1/24	9			1.20	3.02
1/25	10			0.25	3.27
Test 4c (1967)					
1/31	5			0.27	0.27
2/1	6	0.50	0.20		0.47
2/7	12	0.25	0.10		0.57
2/8	13	0.50	0.20		0.77
Test 4d (1967)					
2/25	5			0.15	0.15
3/10	18			Tr	
3/11	19			0.23	0.38
3/12	20			0.95	1.33
3/13	21			0.26	1.59
3/14	22			0.20	1.79
4/2	41			0.25	2.04
4/4	43			0.30	2.34
Test 4e (1967)					
4/11	1			0.68	0.68
4/15	5			0,03	0.71
4/18	8			0.37	1.08
4/19	9			0.34	1.42
4/21	11			0.86	2.28
4/24	14			0.25	2.53

TABLE 4 (Continued)

WATER APPLIED TO CYLINDER 4

	Elapsed Time	Water Added		Rainfall[1]	Total Water Applied
Date	Days	Gal	In	In	In
Test 4f (1967) 4/29	1			0.18	0.18
Test 4g 5/10	5			0.13	0.13
Test 4h					NONE

TABLE 4 (Continued)

WATER APPLIED TO CYLINDER 5

Date	Elapsed Time	Water Added		Rainfall[1]	Total Water Applied
	Days	Gal	In	In	In
Test 5a (1967) 3/27					
Test 5b (1967)					
4/11	0			0.68	0.68
4/15	4			0.03	0.71
4/18	7			0.37	1.08
4/19	8			0.34	1.42
4/21	10			0.86	2.28
4/24	13			0.25	2.53
Test 5c (1967) 4/29	2			0.18	0.18
Test 5d (1967) 5/10	5			0.13	0.13

TABLE 5

REFUSE COMPOSITION

CYLINDER 1

Cylinder Data[1]	Percentage Composition				Average
	Paper	Yard Trimmings	Inerts	Garbage	
Volume	59.0	30.6	8.5	1.9	
Weight	40.8	49.5	7.3	2.4	
Moisture Content[2]	11.9	193.0	1.6	275.0	63.2
Organic Matter[3]	77.1	88.2	81.5[4]		
Density,[8] lbs/cu ft					20.6 (12.6)

CYLINDER 2

Volume	56.2	33.6	6.8	3.4	
Weight	62.1	28.1	5.3	4.5	
Moisture Content[2]	4.4	146.0	0.2	232.0	29.1
Organic Matter[5]	88.5	82.0			
Density,[8] lbs/cu ft					13.6 (10.5)

CYLINDER 3

Volume	60.0	29.4	7.1	3.5	
Weight	66.5	25.1	4.7	3.7	
Moisture Content[2]	4.5	85.6	0.2	258.0	20.9
Organic Matter[5]	83.5	38.5			
Density,[8] lbs/cu ft					14.2 (11.8)

TABLE 5 (Continued)

REFUSE COMPOSITION

CYLINDER 4a

Cylinder Data[1]	Percentage Composition				Average
	Paper	Yard Trimmings	Inerts	Garbage	
Volume	60.0	30.0	8.0	2.0	
Weight	49.6	37.7	7.8	4.9	
Moisture Content	21.3	117.6	7.9	200.0	49.4
Density,[8] lbs/cu ft					19.9 (11.8)

CYLINDER 4b

Volume	60.0	30.0	8.0	2.0	
Weight	NA	NA	NA	NA	
Moisture Content	11.8	212.2	0.6	88.5	
Organic Matter	58.9	96.5	94.4[4]	76.3	
Density,[8] lbs/cu ft					NA

CYLINDER 4c

Volume	60.0	30.0	8.0	2.0	
Weight	65.7	23.9	5.8	4.6	
Moisture Content	7.7	73.6	0.7	57.6	17.7
Organic Matter	99.9	95.7	23.6		
Density,[8] lbs/cu ft					20.6 (14.6)

TABLE 5 (Continued)

REFUSE COMPOSITION

Cylinder Data[1]	Percentage Composition				Average
	Paper	Yard Trimmings	Inerts	Garbage	
Cylinder 4d					
Volume	65.5	25.0	6.3	3.2	
Weight	42.1	44.3	6.0	7.6	
Moisture Content	5.6	206.0	2.4	310.5	60.3
Density,[8] lbs/cu ft.					22.9 (14.3)
Cylinder 4e					
Volume	59.6	29.9	7.1	3.4	
Weight	66.7	20.4	5.4	7.5	
Moisture Content	9.9	119	.8	119.0	31.8
Organic Matter	90.7	97.2	41.7	94.3	79.0
Density,[8] lbs/cu ft					16.1 (12.3)
Cylinder 4f					
Volume	58.6	34.3	5.4	1.7	
Weight	56.3	36.8	2.3	4.6	
Moisture Content	7.0	207.0	1.1	268.0	45.7
Organic Matter	76.8	91.0	18.9	96.5	80.8
Density,[8] lbs/cu ft					15.0 (10.3)

TABLE 5 (Continued)

REFUSE COMPOSITION

Cylinder 4g

Cylinder Data [1]	Percentage Composition				Average
	Paper	Yard Trimmings	Inerts	Garbage	
Volume	54.0	41.7	2.7	1.6	
Weight	68.7	22.2	5.1	4.0	
Moisture Content[2]	11.4	215.0	N.A.	N.A.	35.3
Organic Matter	99.6	84.3	N.A.	N.A.	95.7
Density,[8] lbs/cu ft					25.8 (19.0)

Cylinder 4h

Volume	66.6	25.2	5.2	3.0	
Weight	68.4	25.6	4.3	1.7	
Moisture Content[2]	9.3	122.0	0	124.0	26.2
Organic Matter	99.5	88.5	6.8	95.2	
Density,[8] lbs/cu ft					22.2 (17.6)

TABLE 5 (Continued)

REFUSE COMPOSITION

Cylinder 5a

Cylinder Data [1]	Refuse Composition				Average
	Paper	Yard Trimmings	Inerts	Garbage	
Volume	39.8	37.6	22.0	0.6	
Weight	56.0	33.7	5.9	4.4	
Moisture Content[2]	12.6	365.2	0.4	154.2	55.0
Organic Matter	97.6	87.1	52.2	97.2	92.2
Density,[8] lbs/cu ft					25.7 (16.8)

Cylinder 5b

Volume	50.0	37.7	7.3	5.0	
Weight	61.0	28.6	5.2	5.2	
Moisture Content[2]	101.0	286.0	22.9	228.0	130.0
Organic Matter	98.2	88.9	84.0	88.5	93.2
Density,[8] lbs/cu ft					16.0 (6.9)

Cylinder 5c

Volume	72.5	22.0	3.5	2.0	
Weight	60.5	31.1	1.8	6.6	
Moisture Content[2]	7.0	207.0	1.1	268.0	30.1
Organic Matter	76.8	91.0	18.9	96.5	81.5
Density, lbs/					19.3 (14.9)

TABLE 5 (Continued)

REFUSE COMPOSITION

Cylinder 5d

Cylinder Data[1]	Refuse Composition				Average
	Paper	Yard Trimmings	Inerts	Garbage	
Volume	49.5	41.8	5.3	3.4	
Weight	53.0	34.3	9.4	3.3	
Moisture Content[2]	7.4	179.0	0.4	162.0	38.5
Organic Matter	99.2	92.5	14.2	89.8	86.8
Density,[8] lbs/cu ft					20.2 (14.6)

Cylinder 5e

Volume	66.0	25.0	5.4	3.6	
Weight	69.0	24.0	5.5	1.5	
Moisture Content[2]	9.3	122.0	0.0	124.0	25.0
Organic Matter	99.5	88.5	6.7	95.2	93.5
Density,[8] lbs/cu ft					19.1 (15.3)

1. Moisture content and organic matter on a dry weight basis. Weight is on a wet weight basis.
2. Moisture contents are prior to adding water for compaction.
3. Percent organic matter determined when the soil cover was removed after two months operation. Samples included some soil.
4. Primarily plastics.
5. After 2-1/2 months of operation.
6. Determined before operating cylinder except where noted otherwise.
7. Reference in text to weights and densities are on a dry weight basis.
8. Density is on a wet weight (dry weight) basis.

TABLE 6

BLOWER OPERATION AND AIR DISTRIBUTION
TO TEST CYLINDERS

Dates	Blower discharge	Operation	Distribution to Cylinders cfm			
	cfm	hrs/day	1	2	4	5
(1966)						
12/24	1.4	8	1.4			
12/27	1.4	9	1.4			
12/28	1.4	8	1.4			
12/29	1.4	18	1.4			
12/30	1.4	18	0.7		0.7	
12/31	1.4	22	0.7		0.7	
(1967)						
1/3	1.4	22	0.7		0.7	
1/4	1.4	22	0.7		0.7	
1/5	1.4	22	0.7		0.7	
1/6	1.4	22	0.7		0.7	
1/10	1.4	24	0.47	0.47	0.47	
1/11 - 1/14	9.0	24	4.50	4.50		
1/15 - 1/25	9.4	24	3.13	3.13	3.13	
1/26	9.0	24	4.50	4.50		
1/27 - 1/31	9.4	24	3.13	3.13	3.13	
2/1	9.4	24	3.13	3.13	3.13	
2/2 - 2/7	4.7	24	1.57	1.57	1.57	
2/8 - 2/13	9.5	24	0.50	0.50	8.50	
2/14 - 2/19	1.0	24	0.50	0.50		
2/20 - 2/28	9.5	24	0.50	0.50	8.50	
3/1 - 3/8	9.5	24	0.50	0.50	8.50	
3/8 - 3/17	9.5	24	0.50	0.50	8.50	
3/18	9.5	16	0.50	0.50	8.50	
3/19 - 3/23	9.5	24	0.50	0.50	8.50	
3/23 - 4/6	4.0	24	0.33	0	3.70	
4/7	0.33	24	0.33	0	0	
4/8 - 4/11	4.0	24	0.33	0	3.70	
4/11 - 4/14	7.0	24	0.33	0	3.70	3.0
4/21 - 5/2	7.0	24	0.33	0	3.70	3.0
5/2	0.33	24	0.33	0	0	0
5/4	4.0	24	0.33	0	3.70	0
5/5 - 5/11	7.0	24	0.33	0	3.70	3.0
5/11 - 5/15	7.70	24	0.50	0.50	3.7	2.5
5/15 - 5/22	8.8	24	1.4	1.4	3.5	2.5
5/22 - 5/24	7.66	24	1.33	1.33	2.7	1.7
5/24 - 5/29	7.66	24	1.33	1.33	2.7	1.7
5/29 - 6/1	2.66	24	1.33	1.33	0	0

TABLE 7

UNDERGROUND INCINERATION PILOT STUDIES
CYLINDERS 4 and 5 - OPERATIONAL DATA

Test Cylinder No.	Phase of Operation	Test Duration, Days	Refuse Characteristics						Average Air Flow	Volume Reduction/Day
			Depth in	Weight[1] lb	Density lb/cu ft Wet[2]	Density lb/cu ft Dry	Moisture[3] %	Organic %	cfm	%
4j	Initial		9	51	23	14	60	N.A.		
	Drying	2							6.5	5.1
	At Ignition		8		20	16				
	Rapid Oxidation	2.5							9.5	22
	Residual Oxidation[4]	39	3						8.5	6.4
	Final		1.5	32	40	28	42	85		
4g	Initial		8	56	30	22	35	96		
	Drying	5.5							3.7	2.9
	At Ignition		6.5		37	27				
	Rapid Oxidation	4.5							3.7	17.5
	Residual Oxidation	1	3.4						0.8	0
	Final		3.4	4	3..	39	29	49		
4h	Initial		11	58	22	16	26	93		
	Drying	3							2.7	0
	At Ignition		11		22	18				
	Rapid Oxidation	5							2.7	22.5
	Residual Oxidation	1	1						0	0
	Final		Negligible	4	20	19	6	27		
5..	Initial		12	68	26	17	35	92		
	Drying	3							6.5	3.4
	At Ignition		10		31	20				
	Rapid Oxidation	14							8.5	54.5
	Residual Oxidation	2	Negligible						6.5	0
	Final		Negligible	4	5..	4..	1	11		

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TABLE 7 (Continued)

UNDERGROUND INCINERATION PILOT STUDIES
CYLINDERS 4 and 5 - OPERATIONAL DATA

Test Cylinder No.	Phase of Operation	Test Duration Days	Refuse Characteristics: Depth in	Weight [1] lb	Density lb/cu ft: Wet [2]	Density lb/cu ft: Dry	Moisture [3] %	Organic %	Average Air Flow cfm	Volume Reduction/Day %
5c	Initial		12	55	19	14	30	82		
	Drying	1							3.0	8.3
	At Ignition		11		21	15				
	Rapid Oxidation	3							3.0	19.2
	Residual [4] Oxidation	3	3.8						3.0	2.7
	Final		3	29	38	23	66	63		
5d	Initial		12	58	20	15	39	87		
	Drying	3							3.0	8.4
	At Ignition		10		24	16				
	Rapid Oxidation	4							3.0	18.7
	Residual Oxidation	3	1						2.5	2.7
	Final		Negligible	4	67	66	2	23		
5e	Initial		12	55	19	15	25	94		
	Drying	3.5							1.7	0
	At Ignition		12		19	15				
	Rapid Oxidation	3.5							1.7	26.2
	Residual Oxidation	3	1						0	2.7
	Final		Negligible	5	39	38	2	9		

1. Weight measured on a wet weight basis.
2. Density at ignition calculated assuming no moisture loss during drying.
3. Moisture content on dry weight basis.
4. Height of refuse at beginning of residual oxidation.

TABLE 8

ANALYSIS OF CITY OF SANTA CLARA LANDFILL MATERIAL
(Per cent composition)

Constituents	Fall 1966					Spring 1967				
	Volume	By Wet Weight	By Dry Weight[2]	Moisture Content	Volatile Matter[1]	Volume	By Wet Weight	By Dry Weight[2]	Moisture Content	Volatile Matter
Garden trimmings, grass, etc.	40	35	32	26	95	57	53	37	115	85
Paper	53	53	55	1[illegible]	96	41	43	56	13	86
Metal, glass, and other inerts	3	9	1[illegible]	1	4	1	3	5	1	3
Plastics	2	3	3	2	92	1	1	2	4	95

NOTES:

1. Moisture and volatile percentages are on a dry weight basis.

2. Weight calculations were based on the observed composition by volume and measured density.

TABLE 9

RAINFALL RECORD
DURING GRANT PERIOD
SANTA CLARA, CALIFORNIA

Month	Day	Inches of Rainfall	
		Daily	Cumulative
(1966)			
June			0.00
July	30	.21	.21
August			.21
September	18	.17	.38
October			.38
November	6	.95	
	7	.24	
	15	.18	
	16	.43	
	19	.06	
	20	.73	
	21	.23	
	22	.13	
	28	.37	3.70
December	2	.93	
	3	.04	
	4	.28	
	5	.73	
	6	.49	
	7	.13	
	10	.17	6.47
(1967)			
January	21	1.77	
	22	.80	
	24	1.20	
	25	.03	
	26	.01	
	28	.29	
	29	.60	
	30	.95	
	31	.04	12.16

Source of Data: U.S. Weather Bureau Climatological Data for Santa Clara University.

TABLE 9 (Continued)

RAINFALL RECORD
DURING GRANT PERIOD
SANTA CLARA, CALIFORNIA

Month	Day	Inches of Rainfall	
		Daily	Cumulative
(1967)			
February	15	0.03	
	24	0.08	
	25	0.06	12.33
March	11	1.00	
	12	0.56	
	13	0.36	
	14	0.01	
	15	0.01	
	16	1.45	
	17	0.01	
	20	0.11	
	23	0.01	
	30	0.70	
	31	0.34	16.89
April	4	0.17	
	6	0.76	
	7	0.08	
	10	0.46	
	11	0.28	
	14	0.03	
	15	0.30	
	17	0.18	
	18	0.18	
	19	0.16	
	21	0.53	
	22	0.24	
	23	0.22	
	24	0.06	
	27	0.05	20.59
May	9	0.02	
	11	0.01	20.62

TABLE 10

PRELIMINARY COST AND TECHNICAL SUMMARY
FOR VARIOUS SOLID WASTE DISPOSAL METHODS[1]

Description \ Process	Incineration	Sanitary Landfill	Conventional Composting	Controlled Aeration Biological Incineration
Refuse Composition Before/After Processing				
% by wet weight				
Volatile matter	50/14	50/50	50/45	50/40
Moisture	25/17	25/25	25/25	25/25
Inert	25/69	25/25	25/30	25/35
% by dry weight				
Volatile matter	67/17	67/67	67/60	67/54
Inerts	33/83	33/33	33/40	33/46
Area Required for Processing Facilities, ac	5	0	10	0[2]
Processing Cost				
$/ton of raw refuse	8.00[4]	None	3.00	0.68
$1,000/yr	730		275	62
% Raw Refuse to Disposal Area, Dry Weight Basis	40	100	85	75
In-Place Density of Compacted Fill, lb/yd				
Dry Weight Basis	1000	750	800	850
Wet Weight Basis	1200	1000	1070	1130
Disposal Requirements				
Refuse or Ash 1000/tons yr	33	91	78	68
Landfill Volume, Including Clean Earth and Buffer, ac-ft/yr	41	136	108	90
Area Used, ac[5]	3.4	11.3	9.0	7.5
Disposal Cost[6] $1000/yr	41	114	98	85
Land Cost, $1000/yr[7]	7	23	18	15

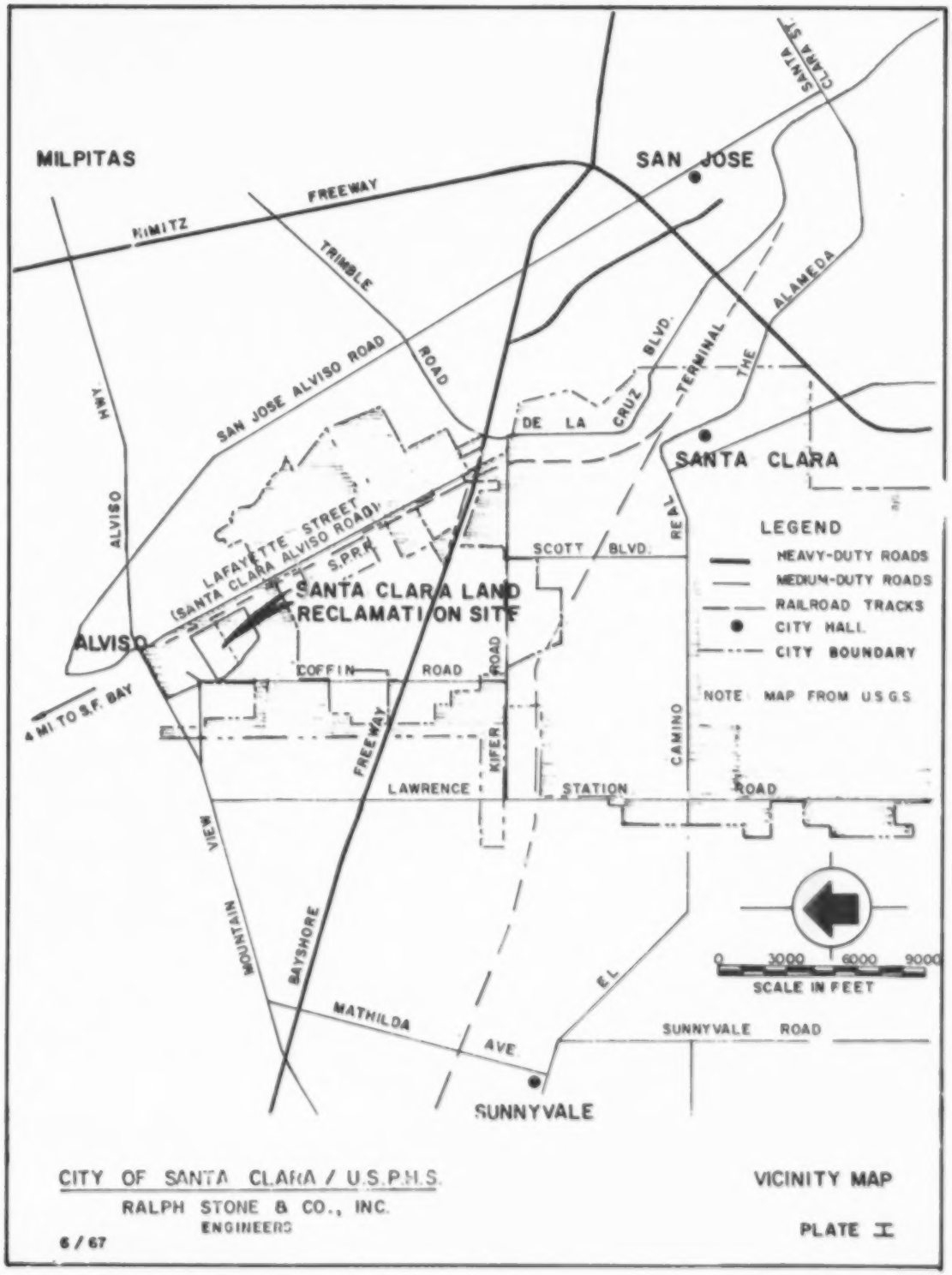
TABLE 10 (Continued)

PRELIMINARY COST AND TECHNICAL SUMMARY
FOR VARIOUS SOLID WASTE DISPOSAL METHODS[1]

Description \ Process	Incineration	Sanitary Landfill	Conventional Composting	Controlled Aeration Biological Incineration
Total Cost of Process/ Treatment and Disposal[8]				
$1000/yr	778	137	391	162
$/ton of raw refuse	8.53	1.50	4.29	1.78
Stability of Reclaimed Fill Land	+	-	Under Study	Under Study

NOTES:

1. Based on a tributary population of 100,000 producing 5 lb/cap/day.
2. The area for processing facilities is ultimately used for disposal. To continuously operate this system, some 18 ac are recommended for processing and disposal.
3. Includes amortization, O & M, supplies and all other expenditures.
4. Includes the cost of hauling the ash and inerts from the incinerator to a landfill site.
5. Based on 12-foot landfill depth, including soil cover.
6. The estimated unit cost of $1.25/ton for landfill operation includes amortization, O & M, supplies and all other expenditures except land purchase.
7. Based on land cost of $2,000 per ac.
8. Based on wet weight of trucked refuse at processing/disposal site; excludes cost of collection or haul to the site.



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VICINITY MAP

PLATE I

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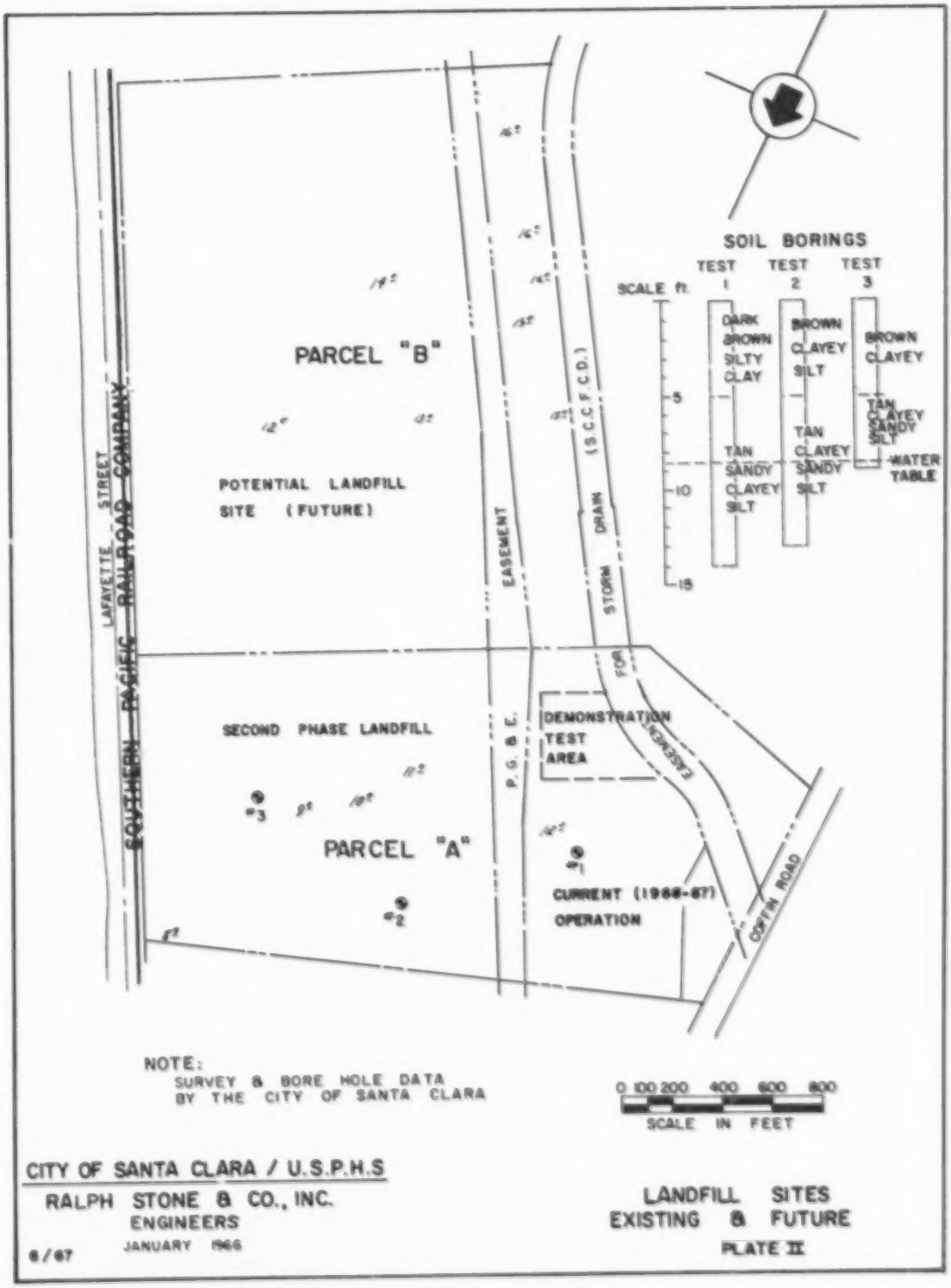
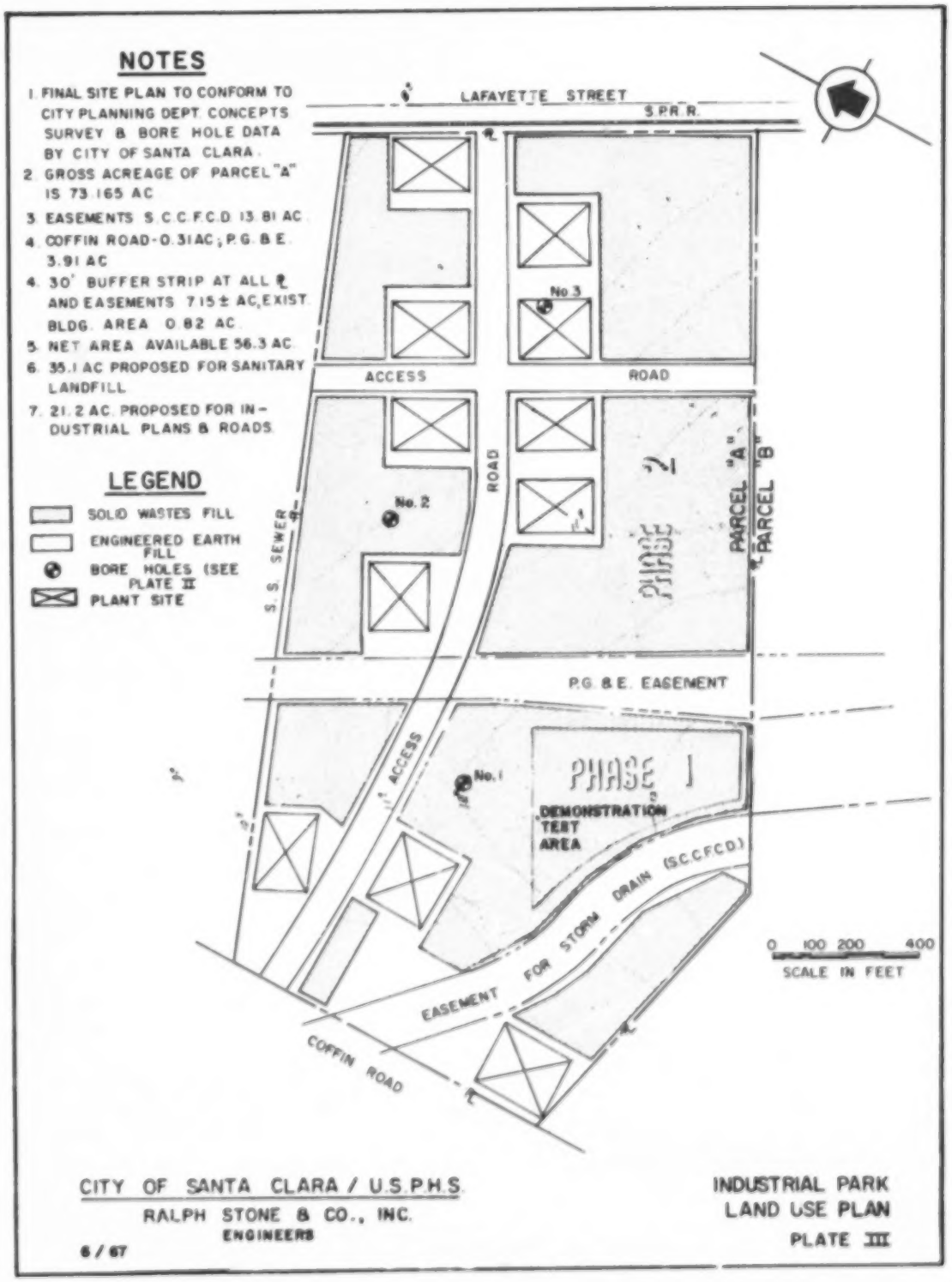

SOIL BORINGS
TEST 1
TEST 2
TEST 3
SCALE ft.
DARK BROWN SILTY CLAY
BROWN CLAYEY SILT
BROWN CLAYEY
TAN CLAYEY SANDY SILT
TAN SANDY CLAYEY SILT
TAN CLAYEY SANDY SILT
WATER TABLE
PARCEL "B"
POTENTIAL LANDFILL SITE (FUTURE)
LAFAYETTE STREET
SOUTHERN PACIFIC RAILROAD COMPANY
EASEMENT
STORM DRAIN (S.C.C.F.C.D.)
SECOND PHASE LANDFILL
P.G. & E.
DEMONSTRATION TEST AREA
FOR EASEMENT
PARCEL "A"
CURRENT (1966-67) OPERATION
COPPER ROAD
NOTE:
SURVEY & BORE HOLE DATA BY THE CITY OF SANTA CLARA
0 100 200 400 600 800
SCALE IN FEET
CITY OF SANTA CLARA / U.S.P.H.S
RALPH STONE & CO., INC.
ENGINEERS
JANUARY 1966
6/67
LANDFILL SITES
EXISTING & FUTURE
PLATE II


NOTES
1. FINAL SITE PLAN TO CONFORM TO CITY PLANNING DEPT. CONCEPTS SURVEY & BORE HOLE DATA BY CITY OF SANTA CLARA.
2. GROSS ACREAGE OF PARCEL "A" IS 73.165 AC.
3. EASEMENTS S.C.C.F.C.D. 13.81 AC.
4. COFFIN ROAD-0.31AC; P.G. & E. 3.91 AC.
4. 30' BUFFER STRIP AT ALL ℄ AND EASEMENTS 7.15± AC, EXIST. BLDG. AREA 0.82 AC.
5. NET AREA AVAILABLE 56.3 AC.
6. 35.1 AC PROPOSED FOR SANITARY LANDFILL.
7. 21.2 AC. PROPOSED FOR INDUSTRIAL PLANS & ROADS.
LEGEND
SOLID WASTES FILL
ENGINEERED EARTH FILL
BORE HOLES (SEE PLATE II)
PLANT SITE
LAFAYETTE STREET
S.P.R.R.
No. 3
ACCESS ROAD
ROAD
PARCEL "A"
PARCEL "B"
PHASE 2
No. 2
S.S. SEWER
P.G. & E. EASEMENT
ACCESS
No. 1
PHASE 1
DEMONSTRATION TEST AREA
EASEMENT FOR STORM DRAIN (S.C.C.F.C.D.)
COFFIN ROAD
0 100 200 400
SCALE IN FEET
CITY OF SANTA CLARA / U.S.P.H.S.
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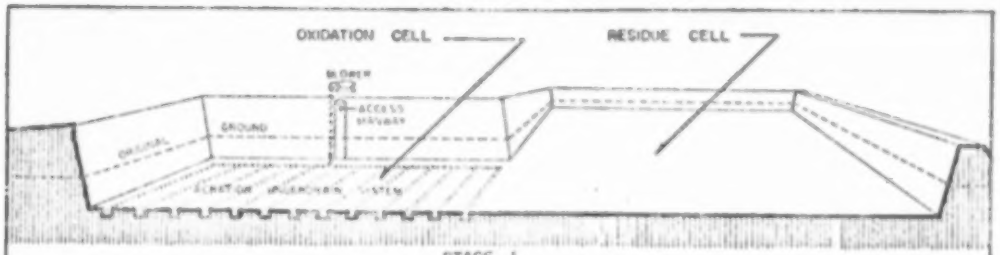
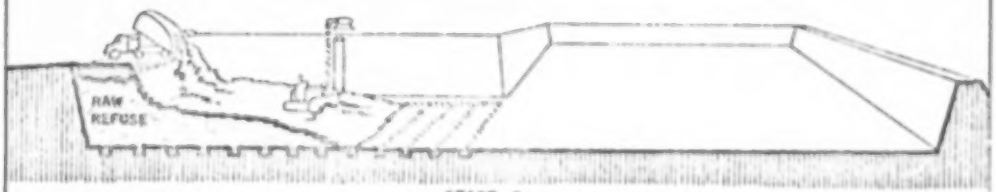
INDUSTRIAL PARK
LAND USE PLAN
PLATE III

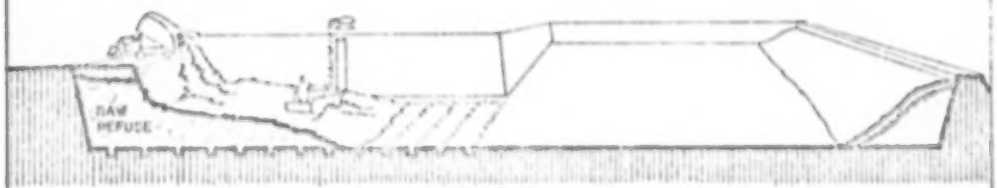


STAGE 1.
SITE PREPARATION



STAGE 2.
RAW REFUSE FILLING

STAGE 3
TRANSFER OXIDIZED RESIDUE FOR DISPOSAL



STAGE 4.
REFILLING WITH RAW REFUSE

STAGE 5.
RECLAIMED SITE

LEGEND

EARTH
EARTH COVER
REFUSE
RESIDUE

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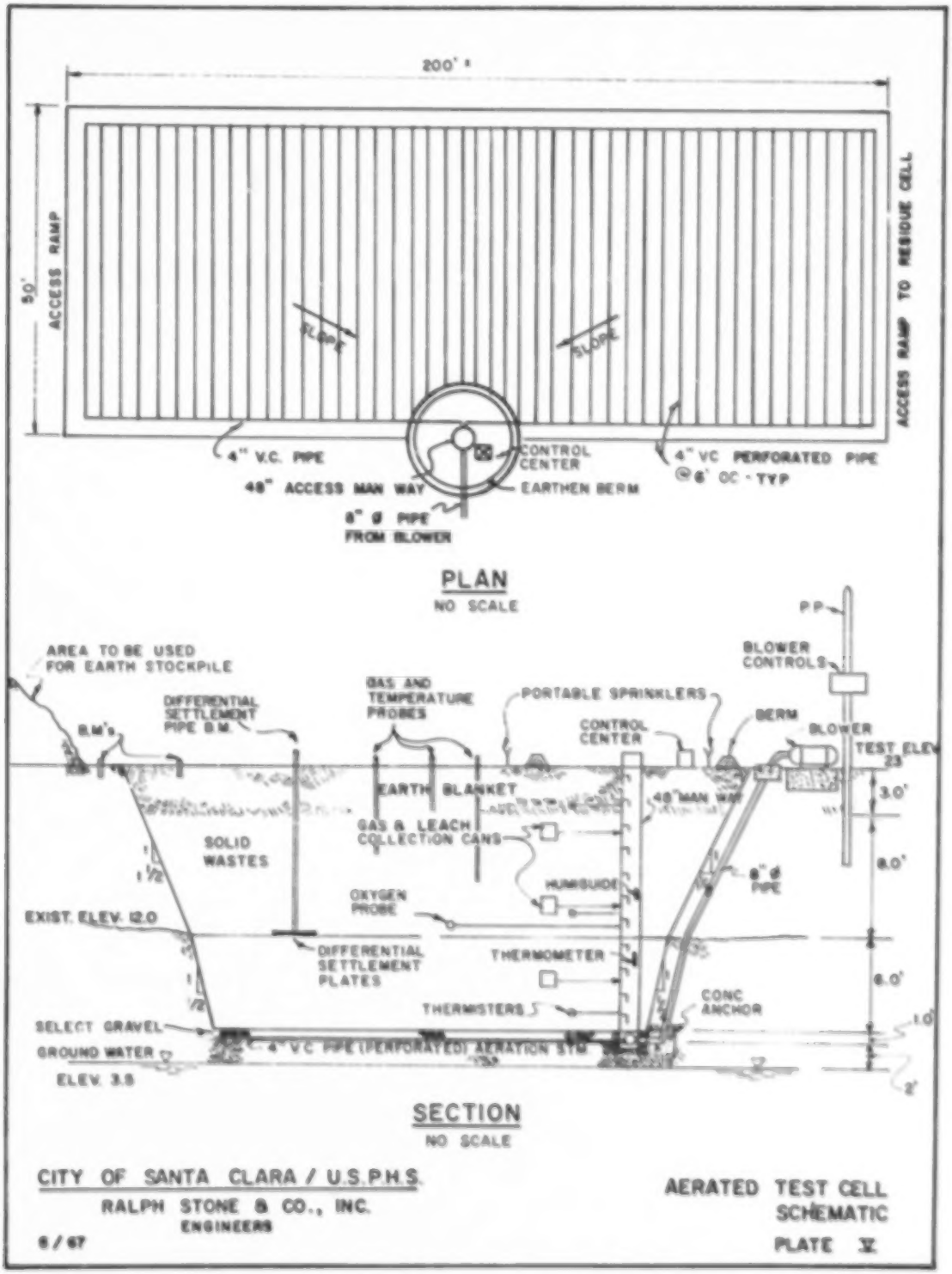
ENGINEERS

OPERATIONAL SEQUENCE
LAND RECLAMATION BY
ACCELERATED STABILIZATION
PLATE #2

70



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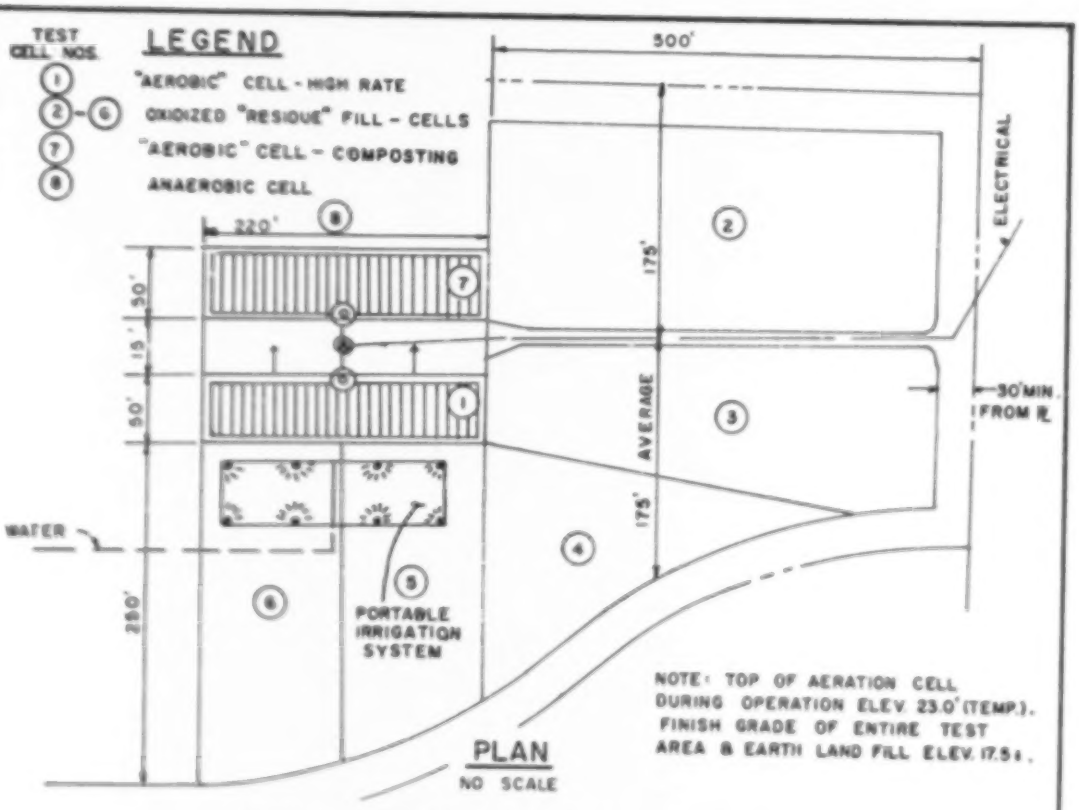
AERATED TEST CELL SCHEMATIC

PLATE V



CHRONOLOGICAL OPERATION SEQUENCE

STEP	EXCAVATION	REFUSE FILL & OXIDATION	EARTH FILL & RESIDUE BACKFILL	STOCKPILE
I	①, ② & ③		FILL PERIPHERIES OF ①, ② & ③	EXCESS CLEAN EARTH ON ⑧ & ⑨
II		①	BACKFILL ②	USE FOR CLEAN EARTH BLANKET ①
III		①	BACKFILL ②	USE FOR TOP 1' CLEAN EARTH BLANKET ①
IV	④	①	BACKFILL ② & ③	CLEAN EARTH FROM ④, USE FOR TOP 1' BLANKET ON ① & ②
V		①	BACKFILL ③	USE FOR TOP 1' CLEA' EARTH BLANKET ①
↓	STEPS III TO V REPEATED UNTIL ② - ⑨ ARE FILLED W/ RESIDUE			USE STOCKPILED CLEAN EARTH TO FILL ADJ. AREA
VI		①		RESIDUE ON ⑧
VII		①	BACKFILL ①	USE FOR TOP 1' CLEAN EARTH BLANKET ①

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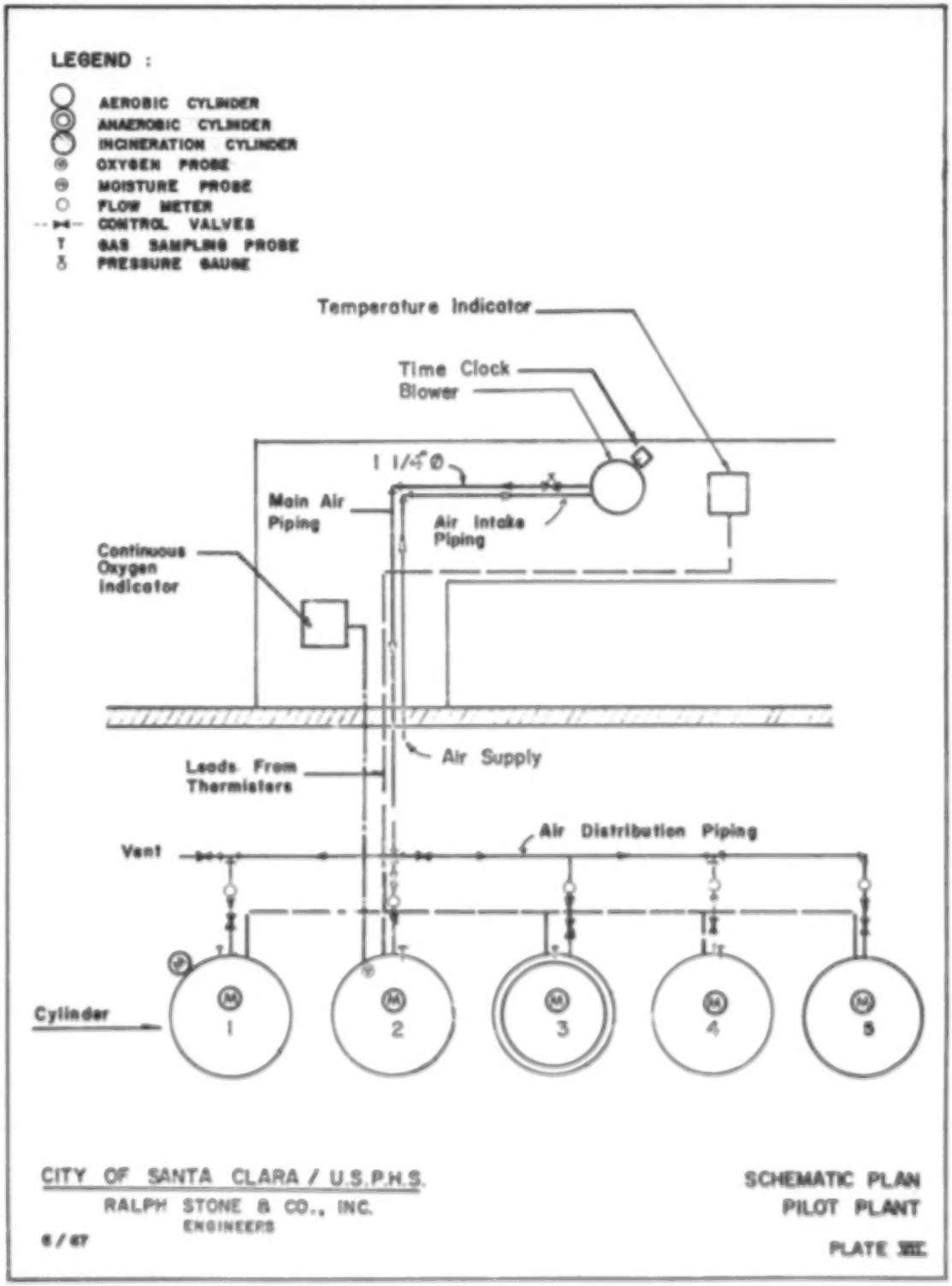
SCHEMATIC PLAN
DEMONSTRATION CELL OPERATION

PLATE VI


LEGEND :
AEROBIC CYLINDER
ANAEROBIC CYLINDER
INCINERATION CYLINDER
OXYGEN PROBE
MOISTURE PROBE
FLOW METER
CONTROL VALVES
GAS SAMPLING PROBE
PRESSURE GAUGE
Temperature Indicator
Time Clock
Blower
1 1/4" Ø
Main Air Piping
Air Intake Piping
Continuous Oxygen Indicator
Air Supply
Leads From Thermisters
Air Distribution Piping
Vent
Cylinder
1
2
3
4
5
CITY OF SANTA CLARA / U.S.P.H.S.
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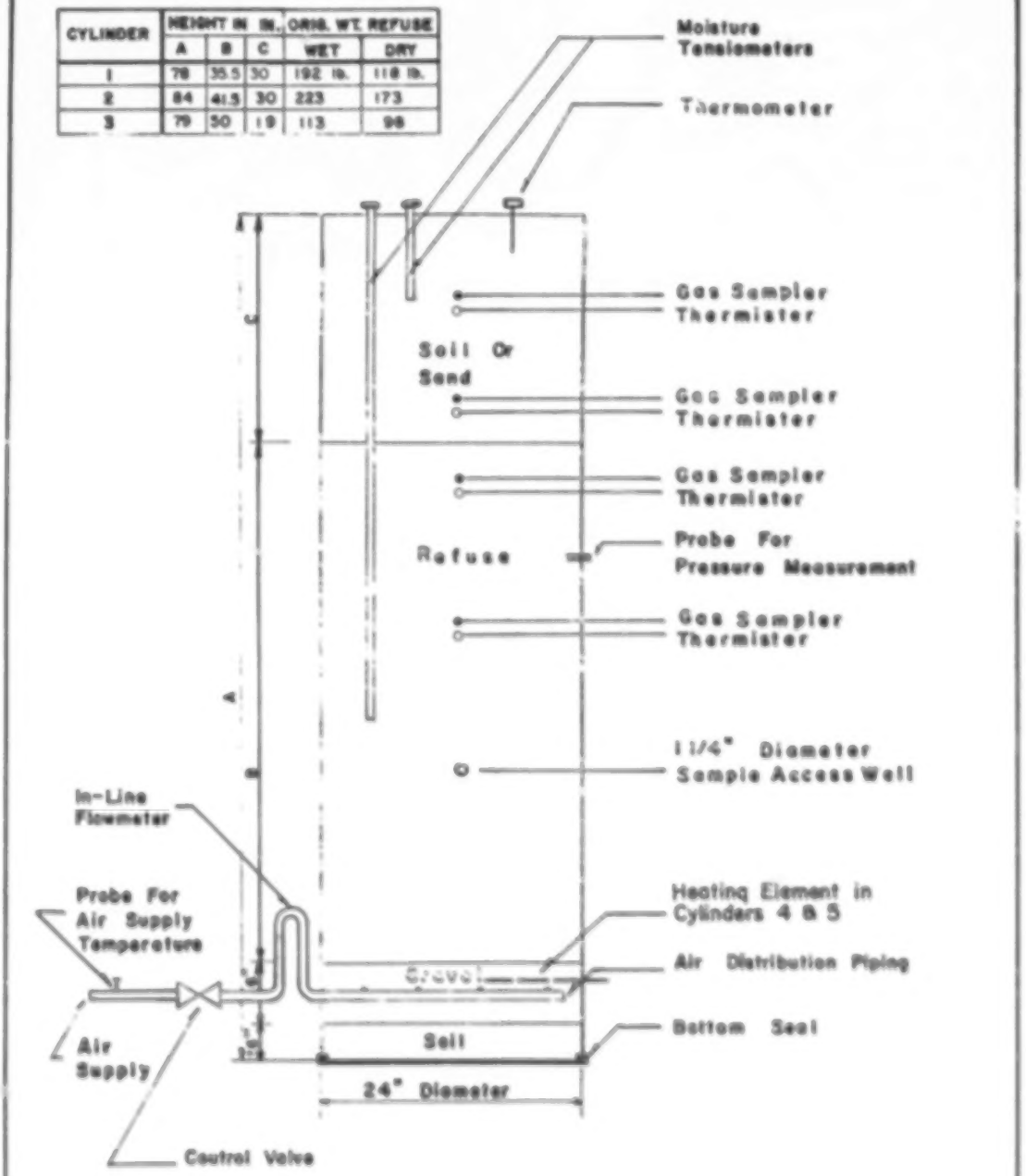
SCHEMATIC PLAN
PILOT PLANT
PLATE XII.

CYLINDER	HEIGHT IN IN.			ORIG. WT. REFUSE	
	A	B	C	WET	DRY
1	78	35.5	30	192 lb.	118 lb.
2	84	41.5	30	223	173
3	79	50	19	113	98



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TYPICAL BIOLOGICAL PILOT PLANT

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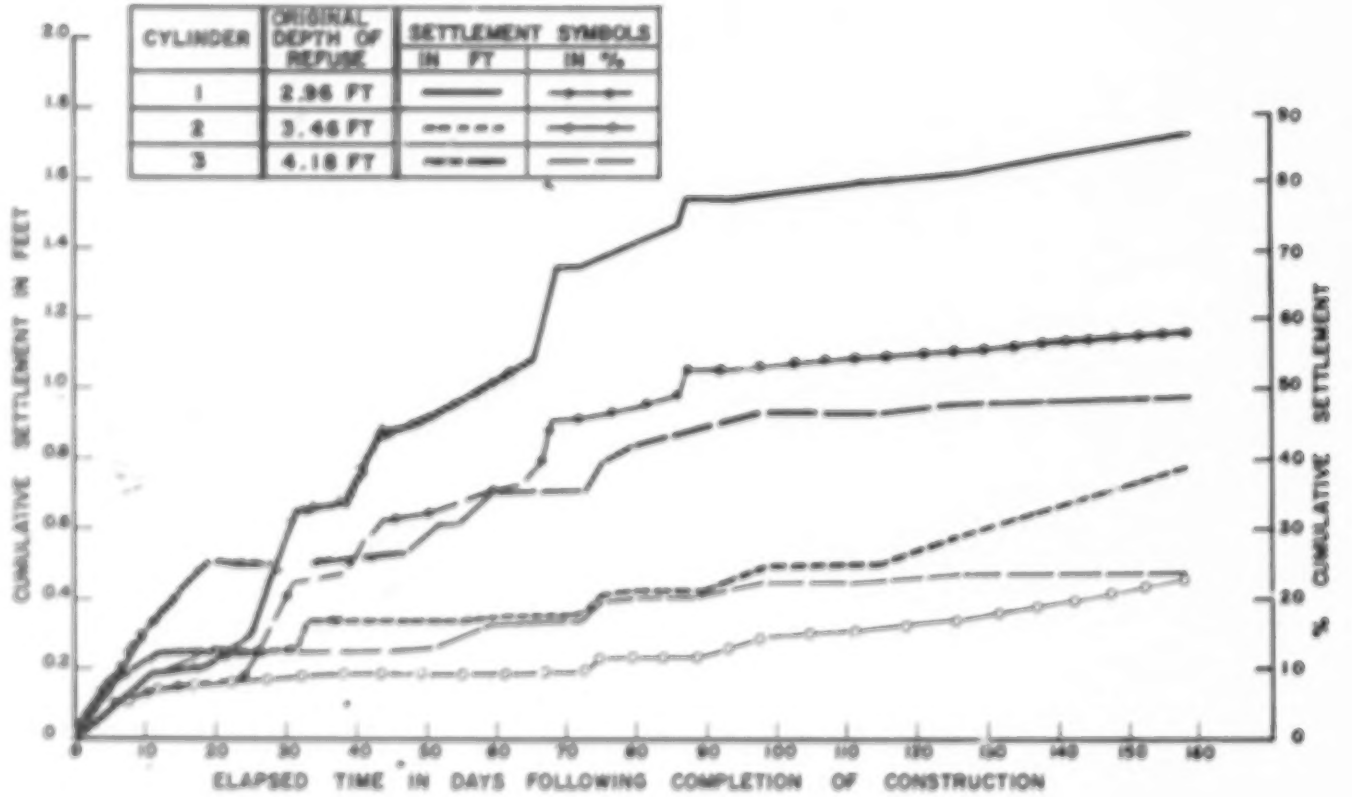
PLATE VIII



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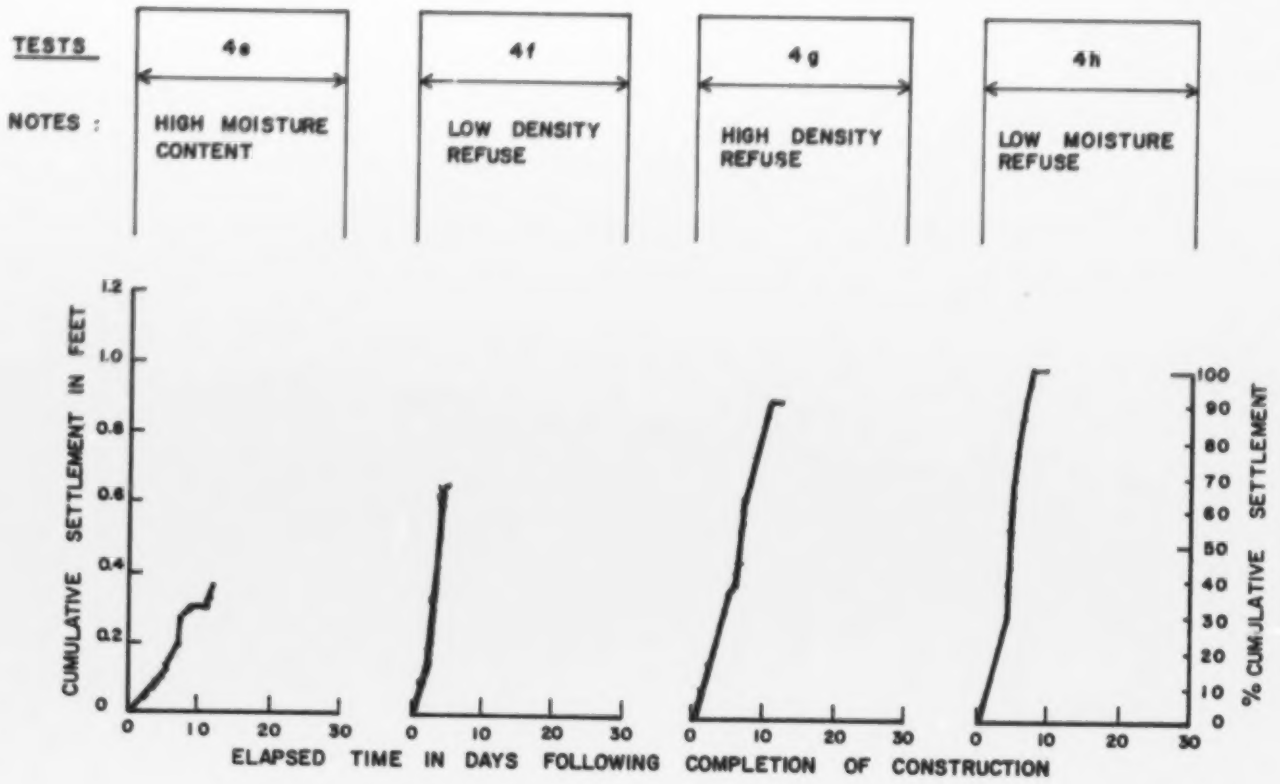
SETTLEMENT
CYLINDERS 1, 2 & 3

PLATE IX



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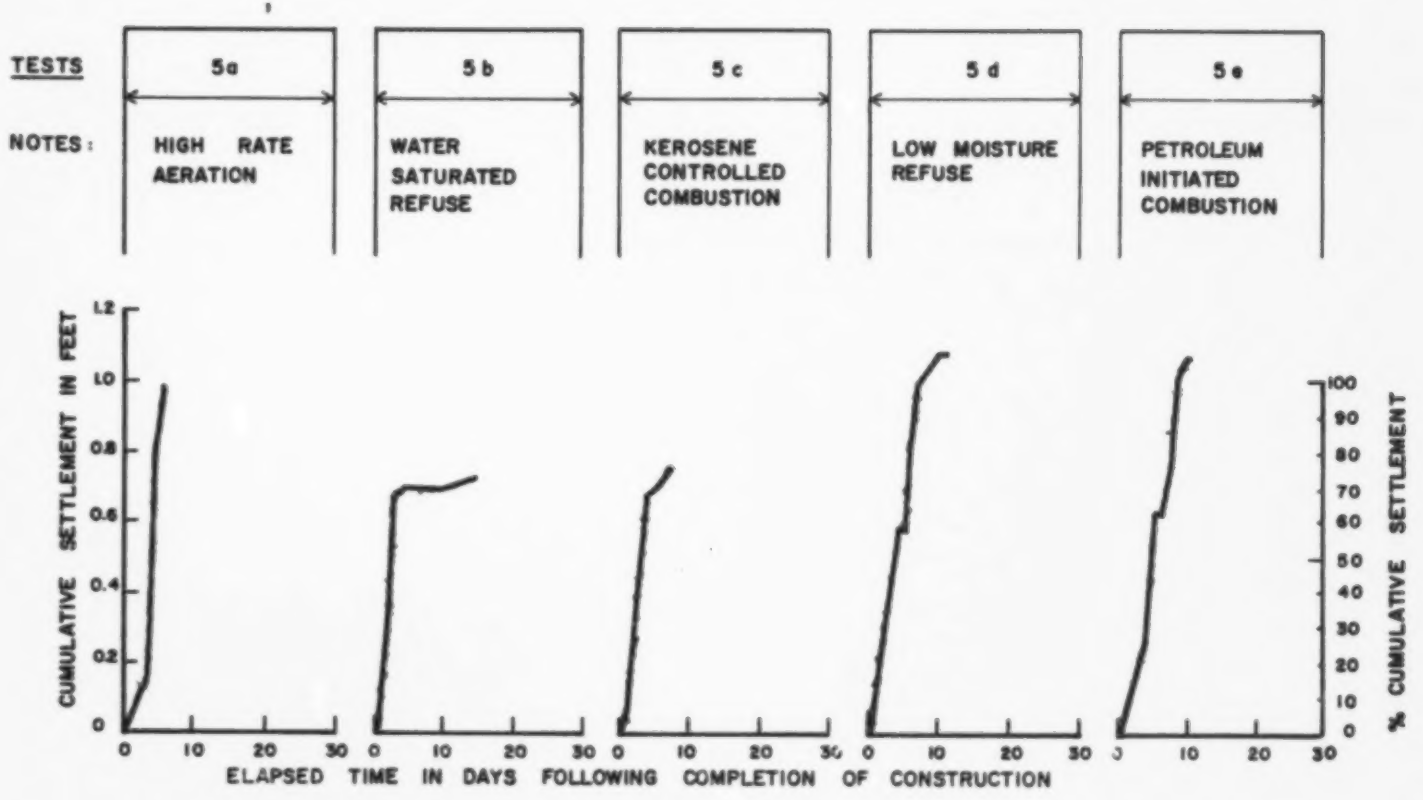
SETTLEMENT
CYLINDER 4

PLATE XI



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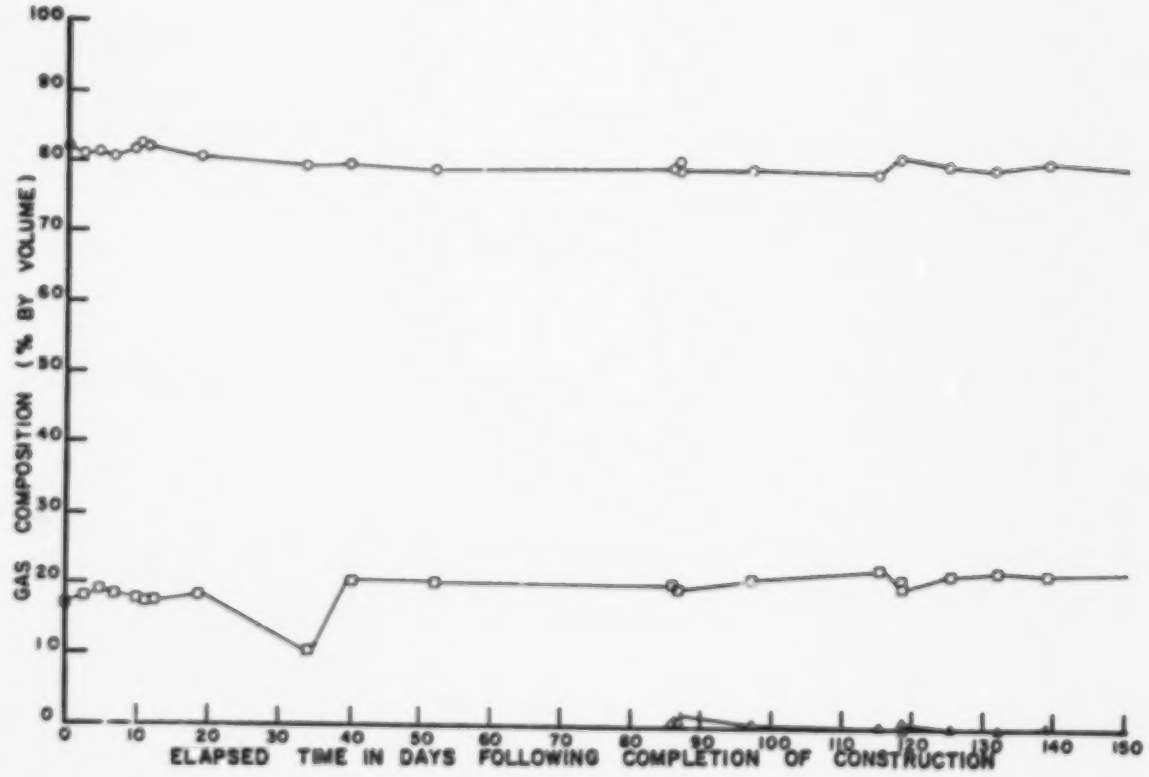
SETTLEMENT
CYLINDER 5

PLATE XII



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LEGEND:

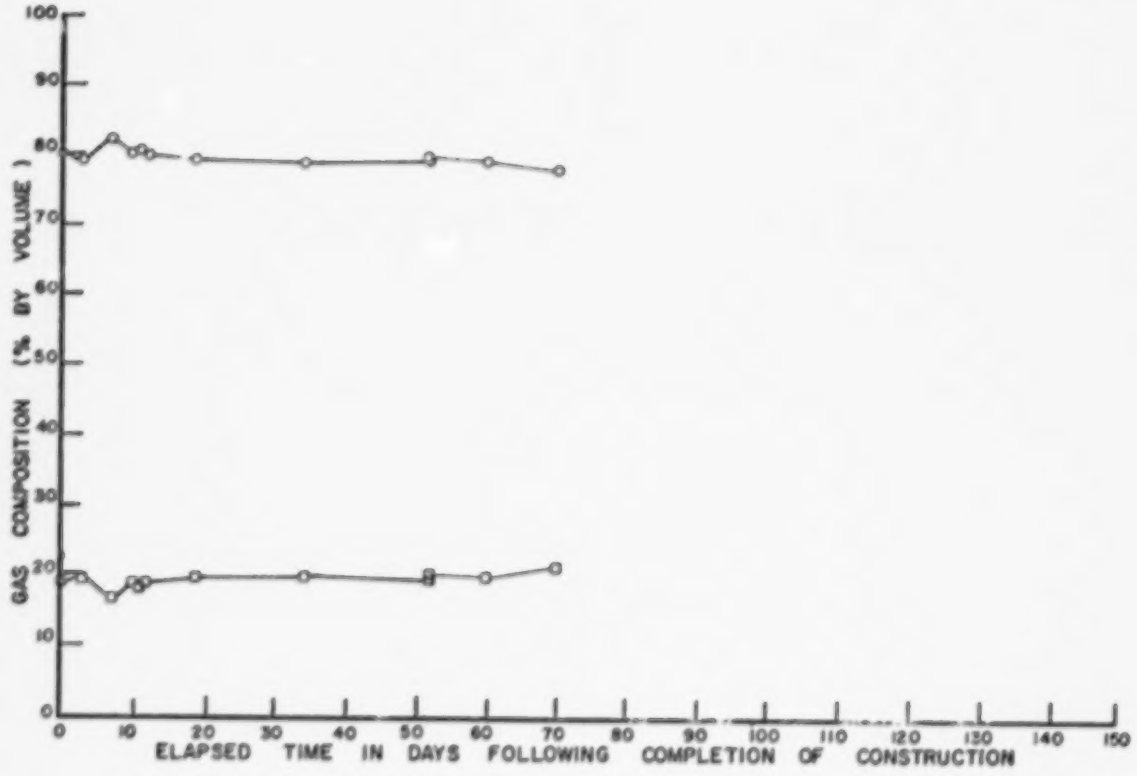
N_2

O_2

CO_2

GAS COMPOSITION IN REFUSE CYLINDER 1

PLATE XIII



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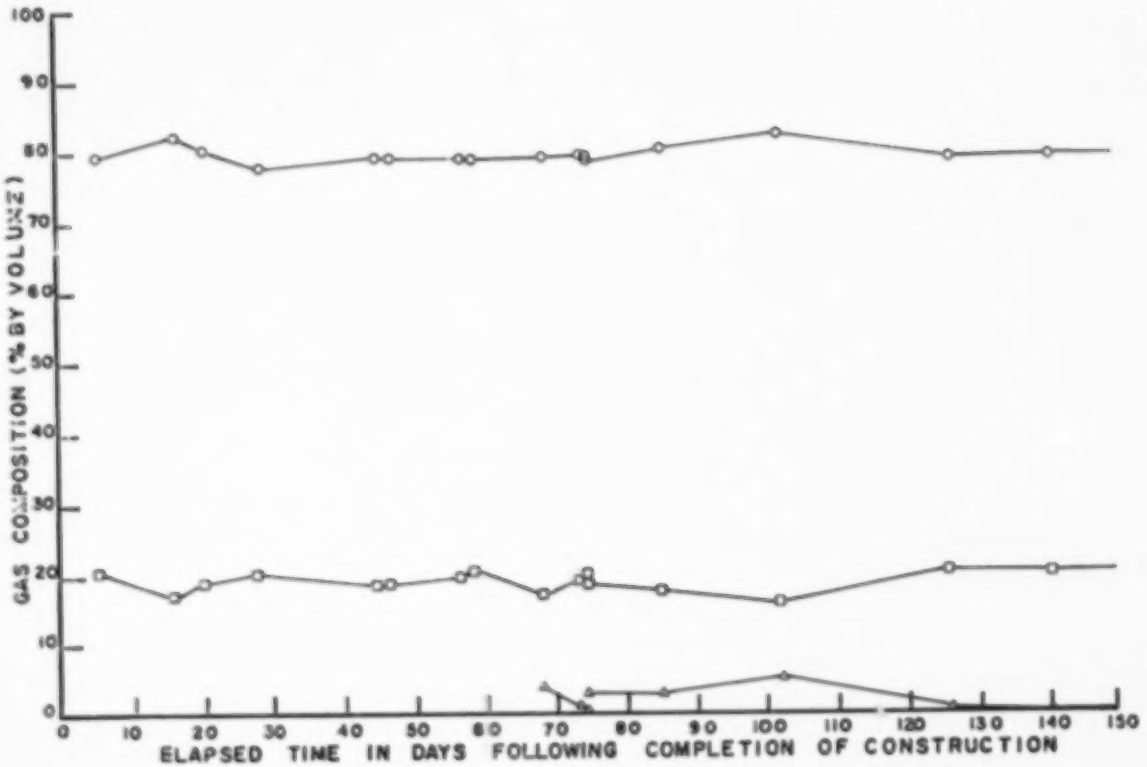
6/67

LEGEND:

N_2 ○—○—○

O_2 ○—○—○

GAS COMPOSITION
IN SOIL BLANKET
CYLINDER 1
PLATE XIX



CITY OF SANTA CLARA/ U.S.P.H.S.

RALPH STONE & CO., INC.
ENGINEERS

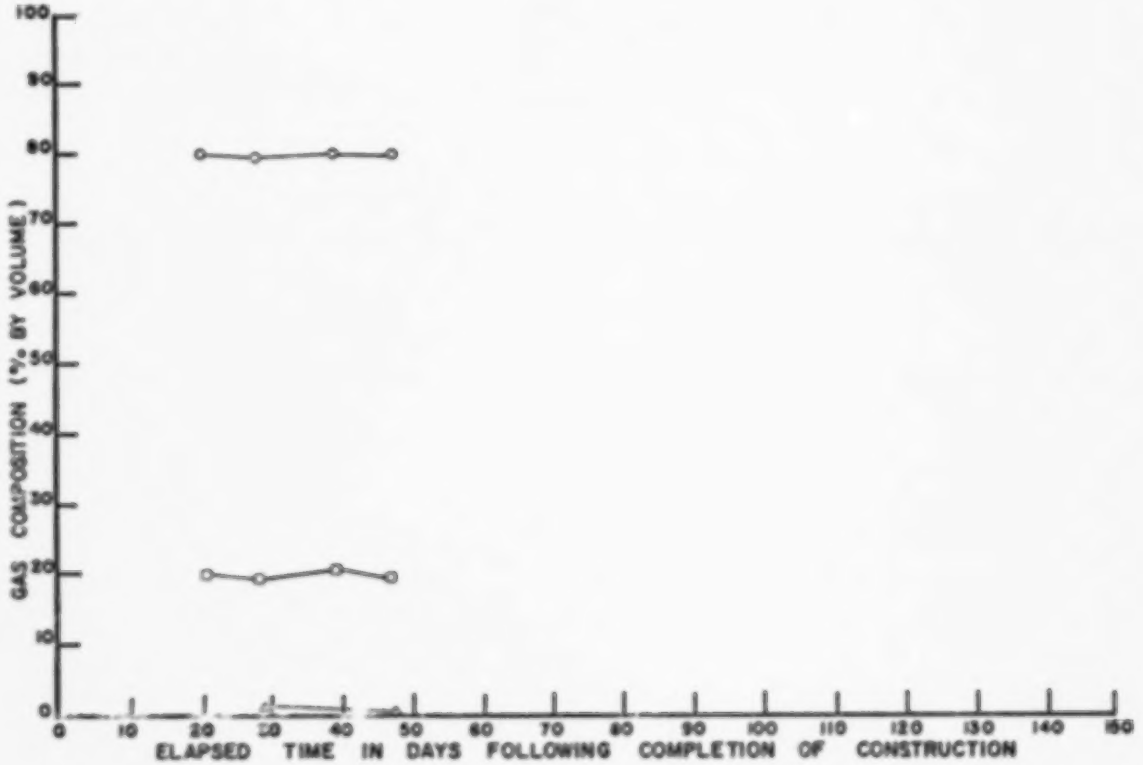
6 / 67

LEGEND:

N_2
O_2
CO_2

GAS COMPOSITION
IN REFUSE
CYLINDER 2

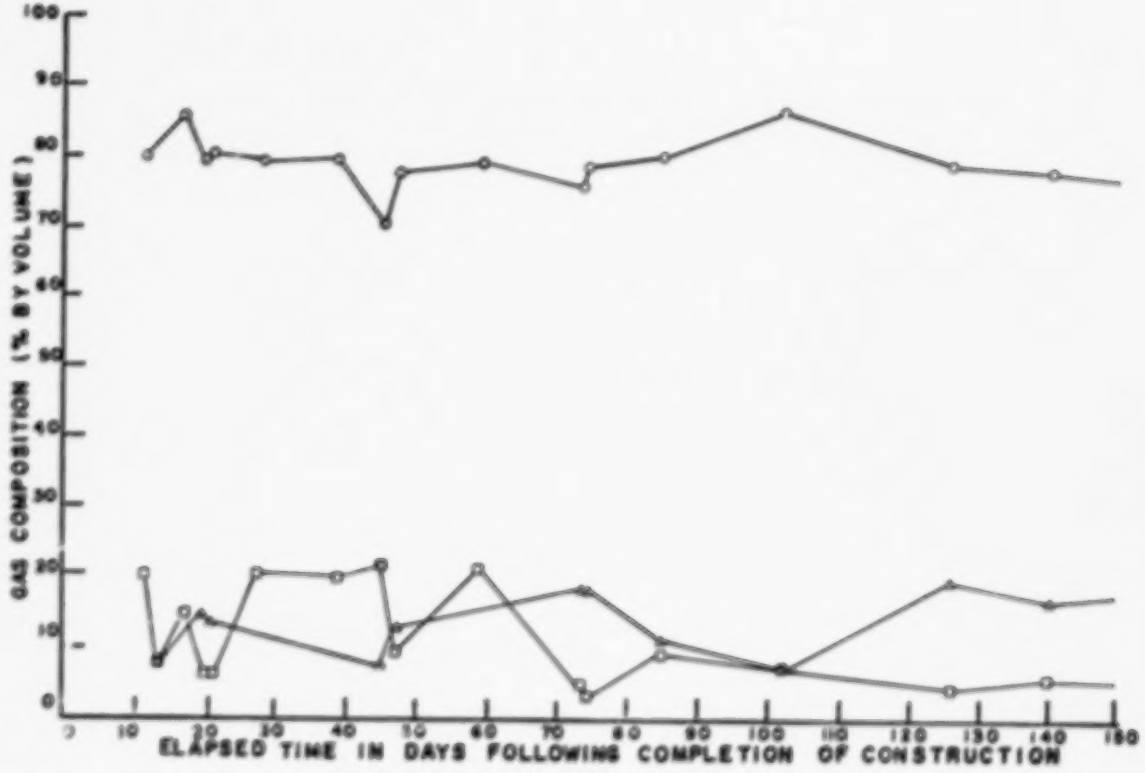
PLATE XX



CITY OF SANTA CLARA / U.S.P.H.S.
RALPH STONE & CO., INC.
ENGINEERS
8/67

LEGEND:
N_2
O_2
CO_2

GAS COMPOSITION
IN SOIL BLANKET
CYLINDER 2
PLATE XXI



CITY OF SANTA CLARA / U.S.P.H.S.

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ENGINEERS

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LEGEND

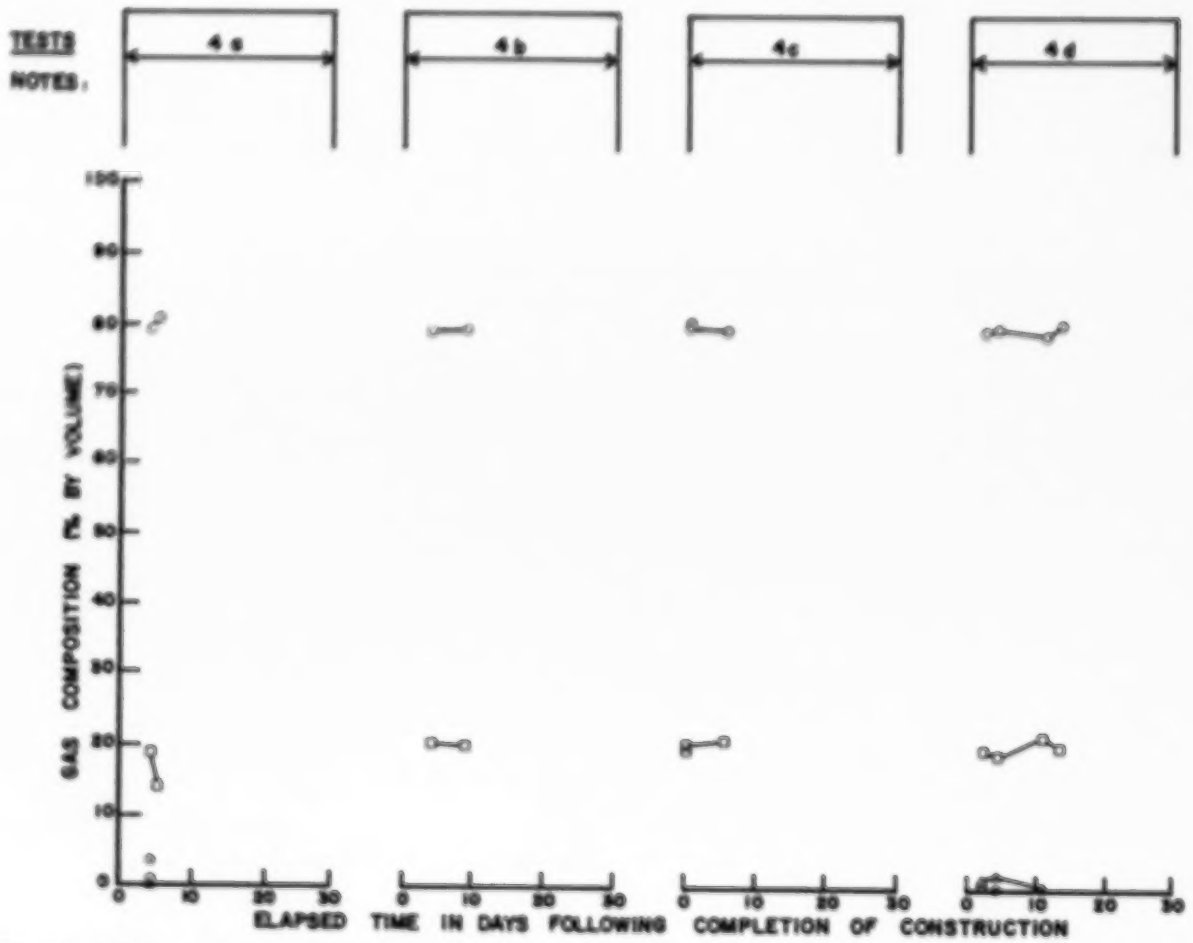
N_2

O_2

CO_2

GAS COMPOSITION
IN REFUSE
CYLINDER 3

PLATE XXIII



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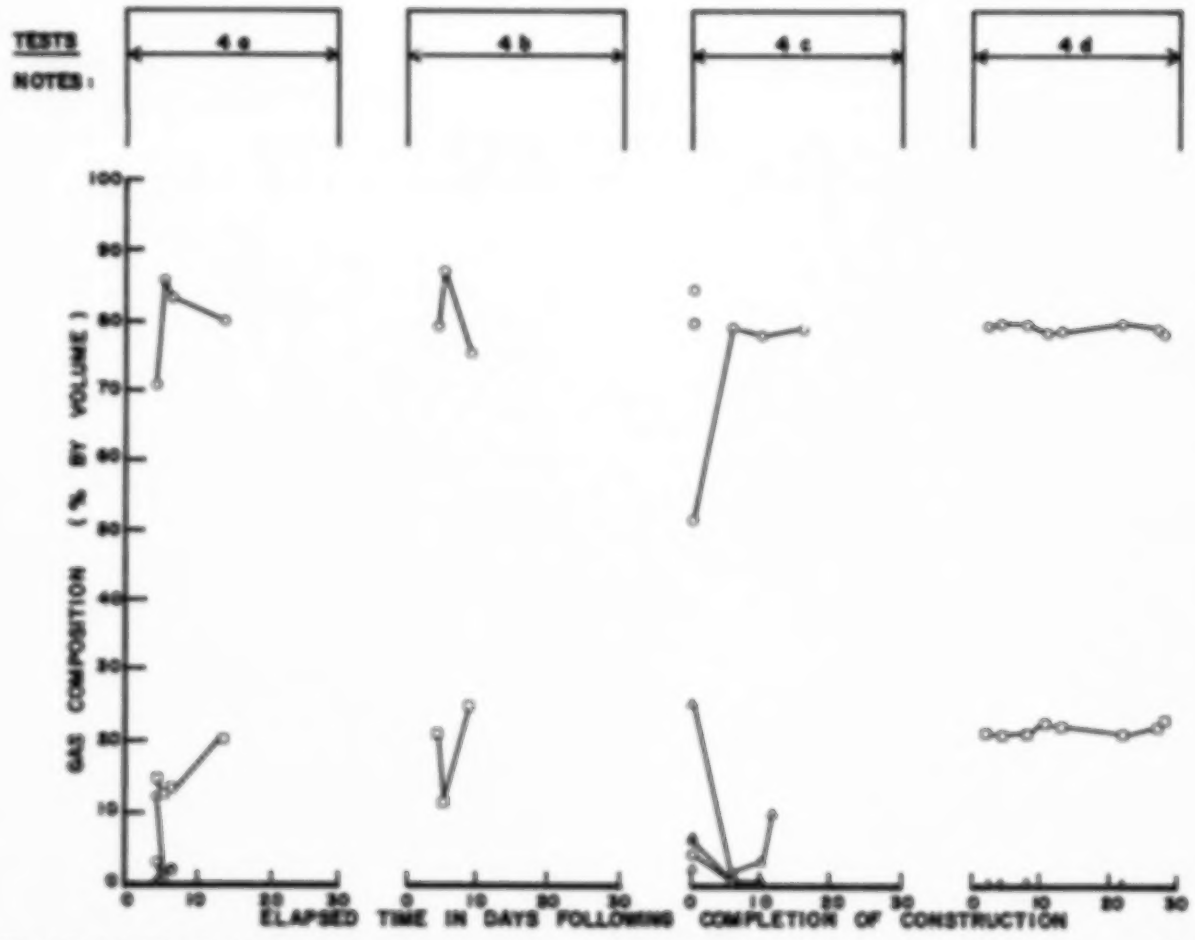
LEGEND:

N_2 O_2 CO_2 CO CH_4

GAS COMPOSITION
IN SOIL BLANKET
CYLINDER 4

PLATE XXVIII



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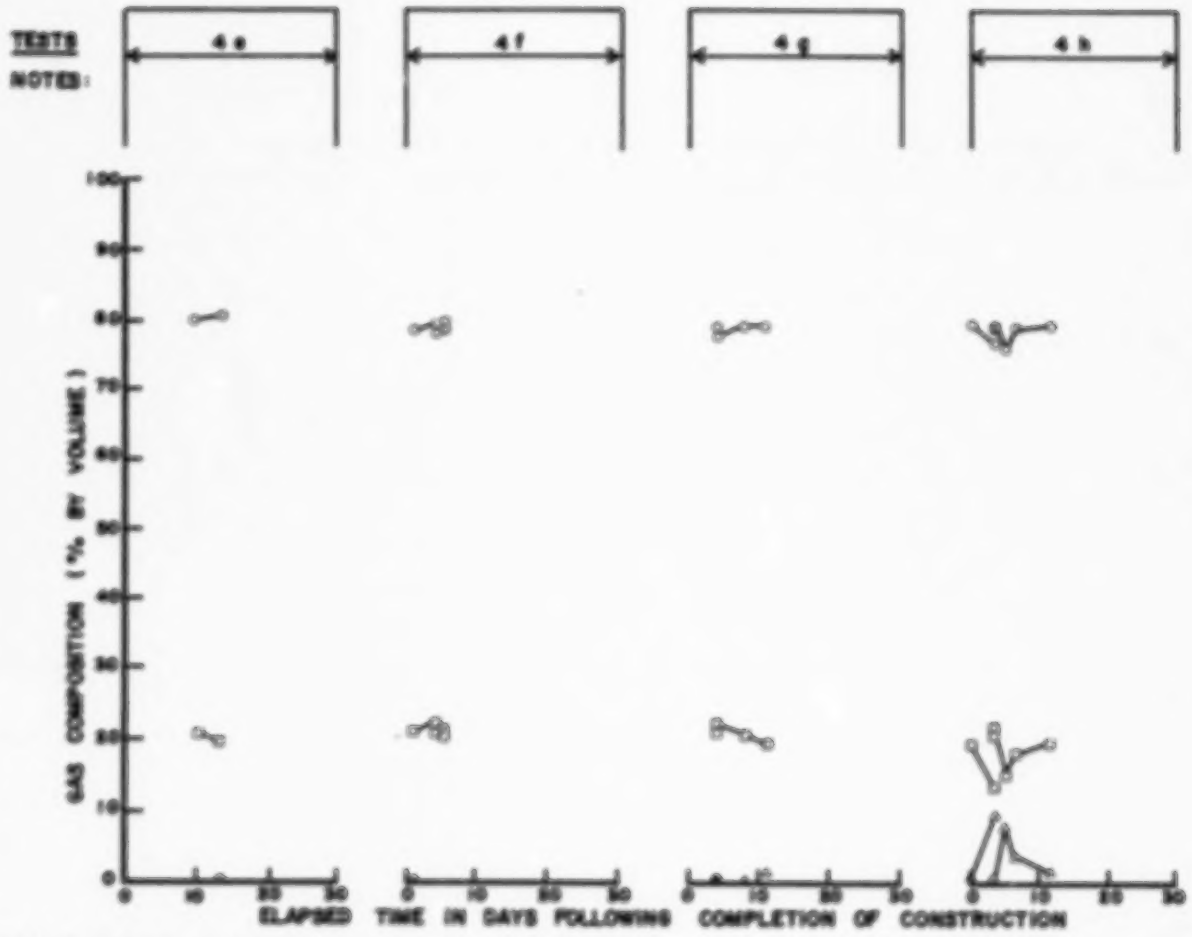
LEGEND :

N_2 O_2 CO_2 CO CH_4

GAS COMPOSITION IN REFUSE
CYLINDER 4
PLATE XIX



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LEGEND :

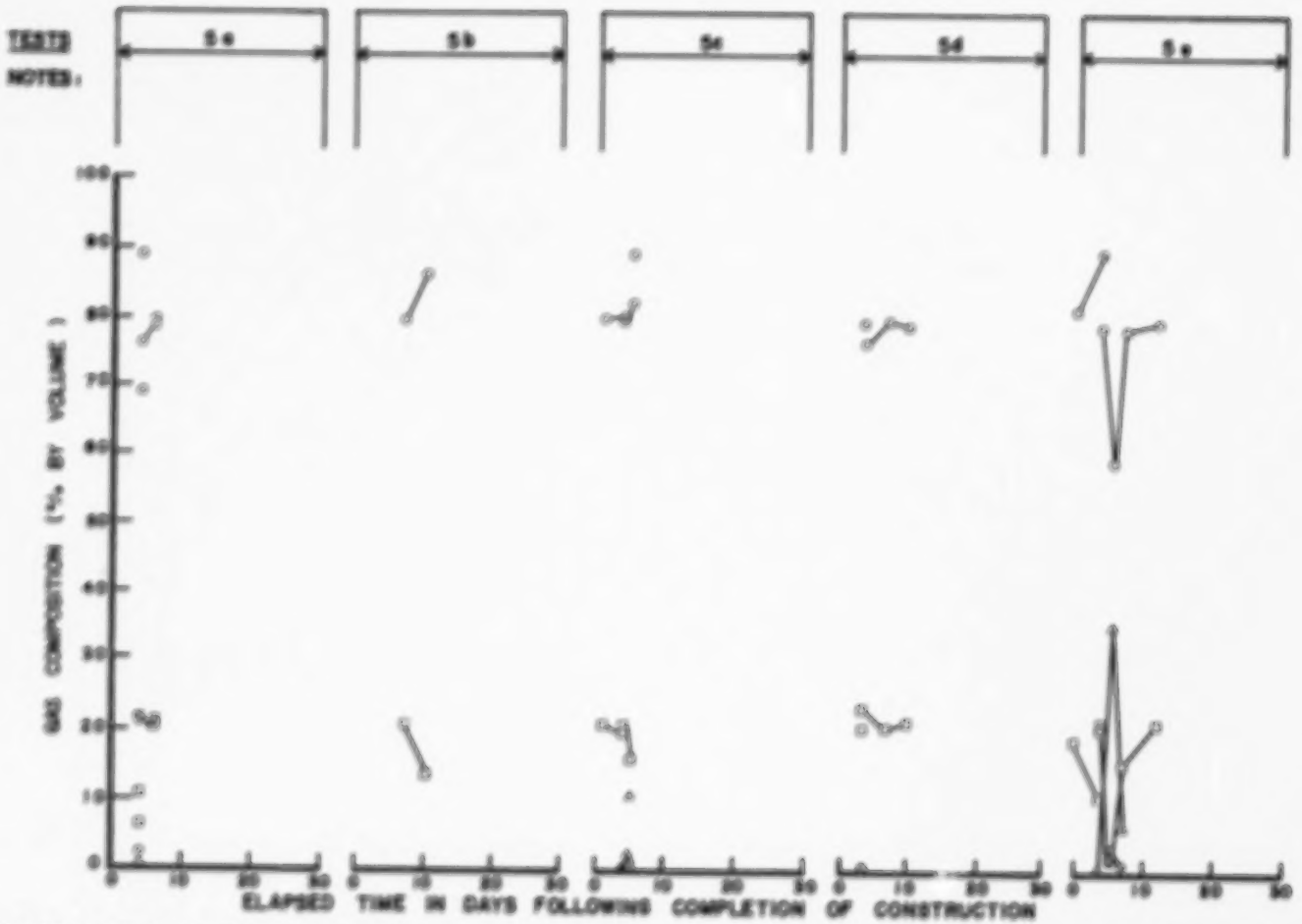
N_2 CH_4

O_2

CO_2

GAS COMPOSITION IN REFUSE CYLINDER 4

PLATE XX



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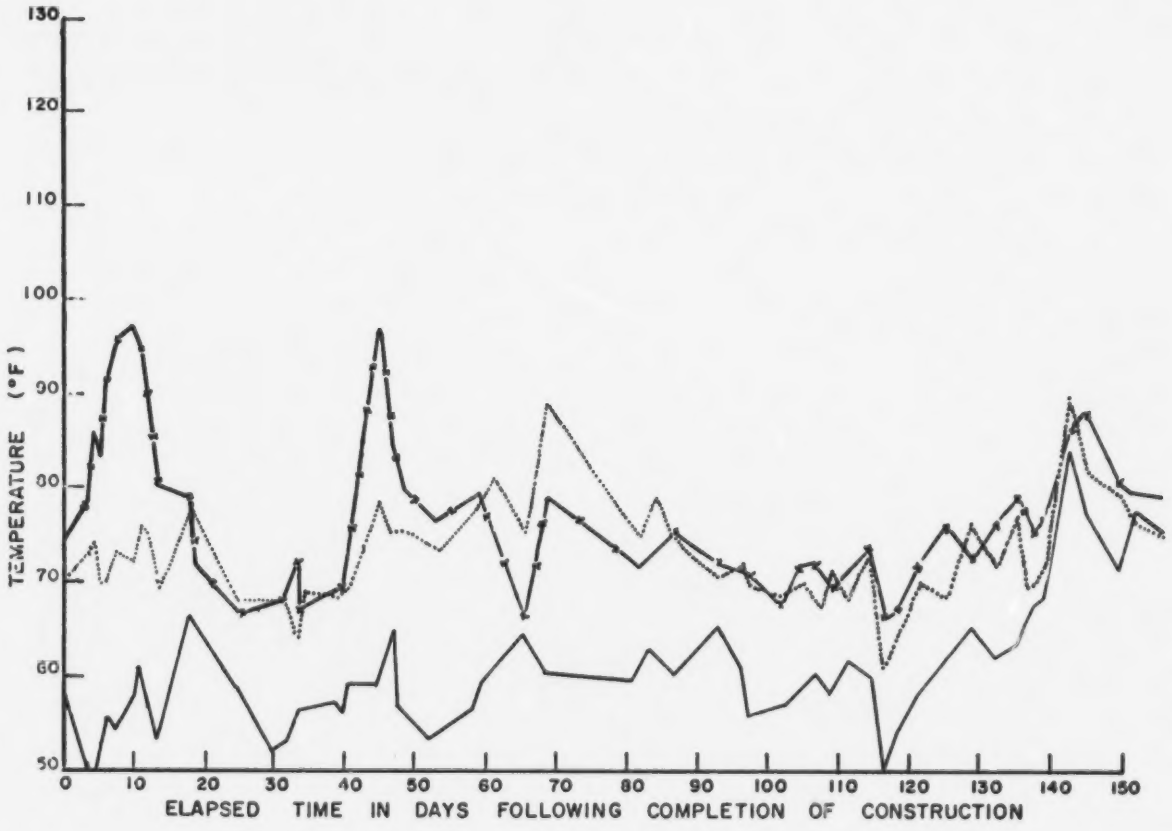
LEGEND :

N_2 CO
O_2 CH_4
CO_2

GAS COMPOSITION IN REFUSE
CYLINDER 5
PLATE XXI



LEGEND:
AMBIENT (AVER)
IN SOIL BLANKET
IN REFUSE

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RALPH STONE & CO., INC.
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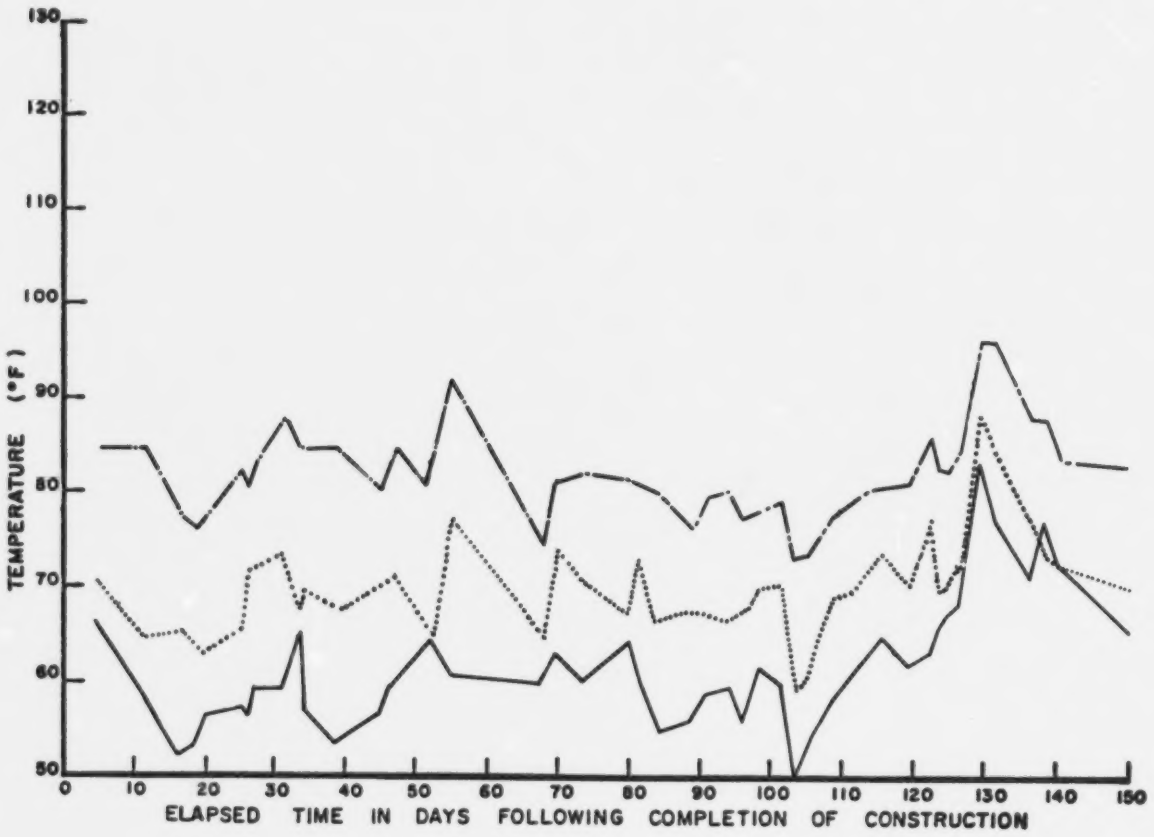
TEMPERATURES
CYLINDER 1
PLATE XXII



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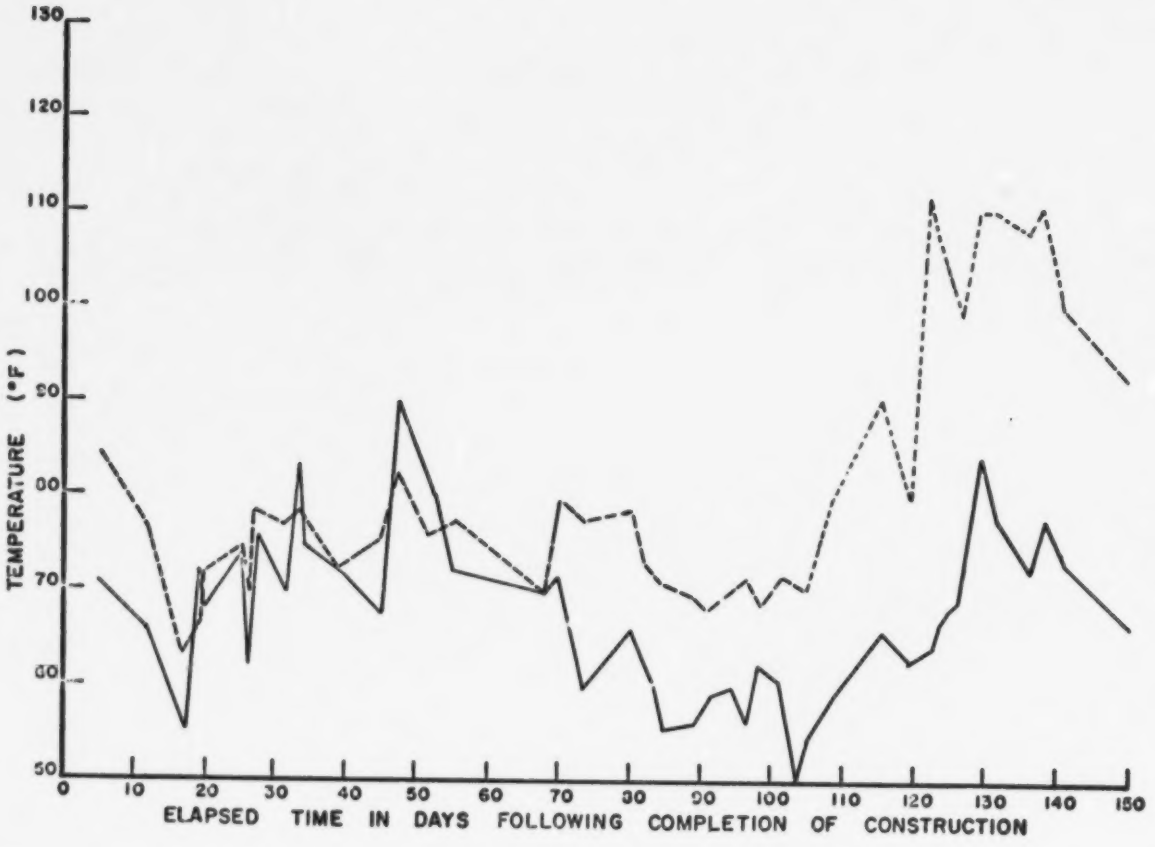
LEGEND :

AMBIENT (AVER.) ——————

IN SOIL BLANKET ....

IN REFUSE —·—·—·—

TEMPERATURES
CYLINDER 2
PLATE XXIII



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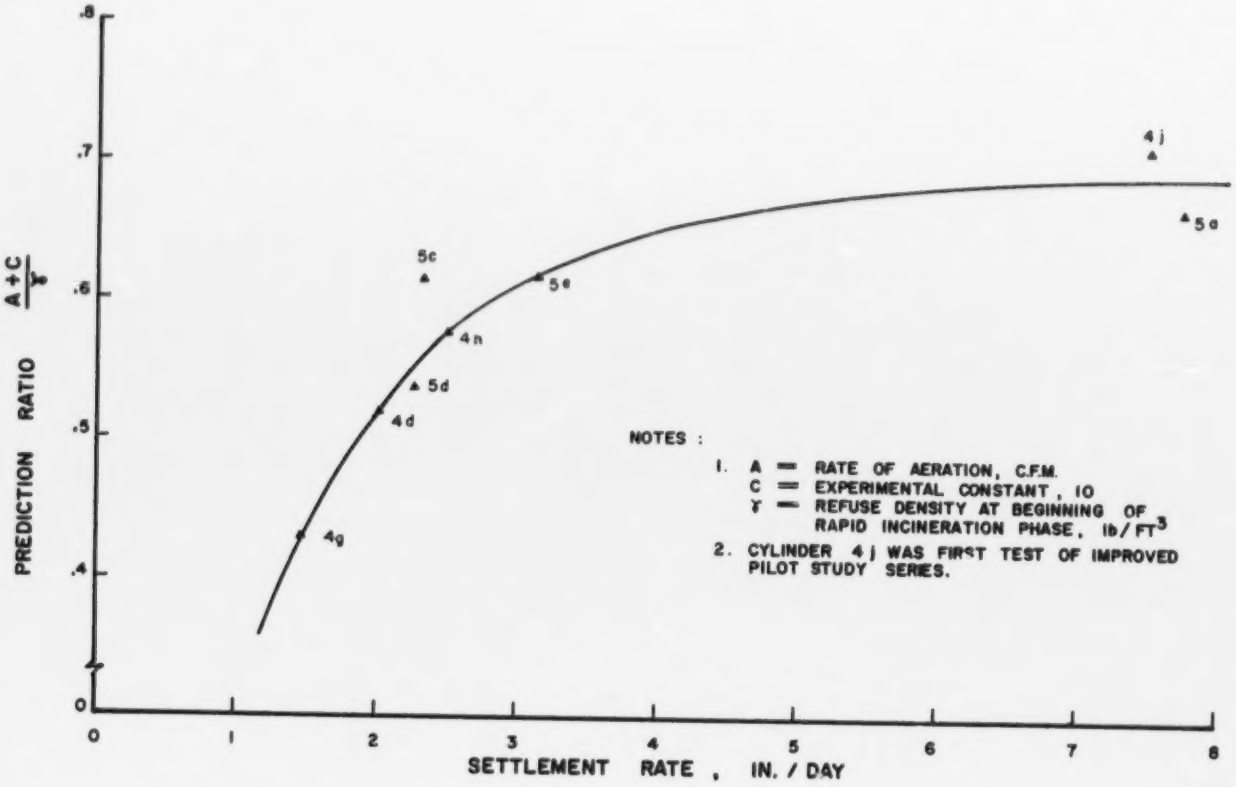
LEGEND:

AMBIENT (AVER) ————
IN REFUSE ----------

TEMPERATURES
CYLINDER 3

PLATE XXIV



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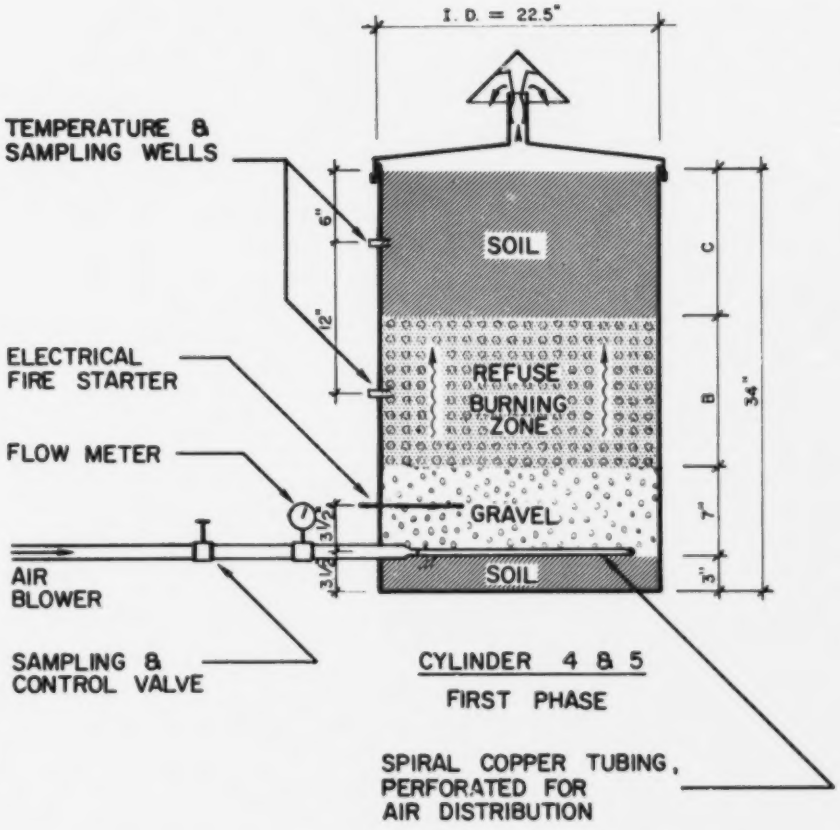
INCINERATION
STUDY RESULTS

PLATE XXV

CYLINDER	HEIGHT IN IN.			ORIG. WT. REFUSE	
	A	B	C	WET	DRY
4	34	11*	11*	51*	38* lb.
5	34	12▲	11▲	55▲	37▲

* AVERAGE OF 8 TESTS
▲ AVERAGE OF 5 TESTS



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RALPH STONE & CO., INC.
ENGINEERS

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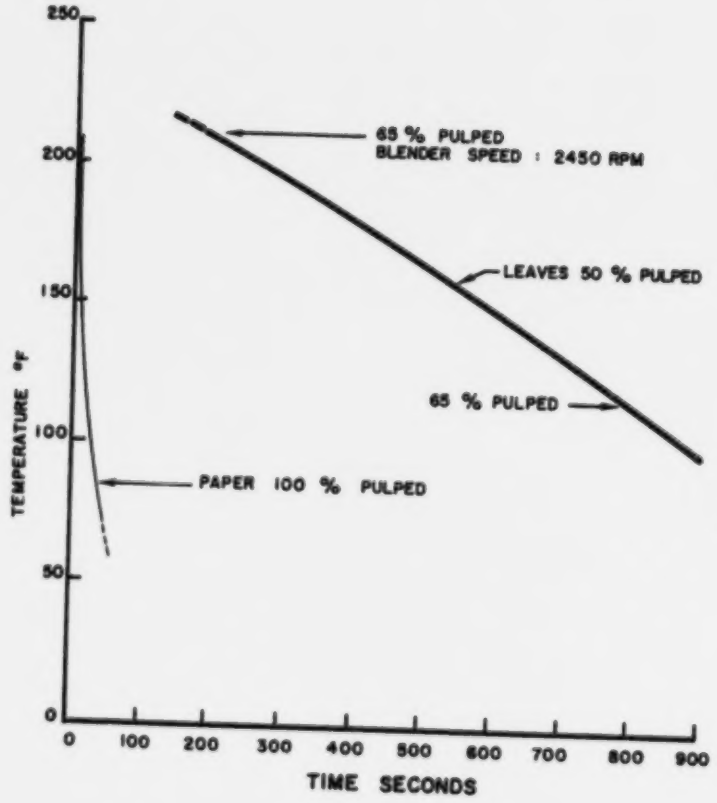
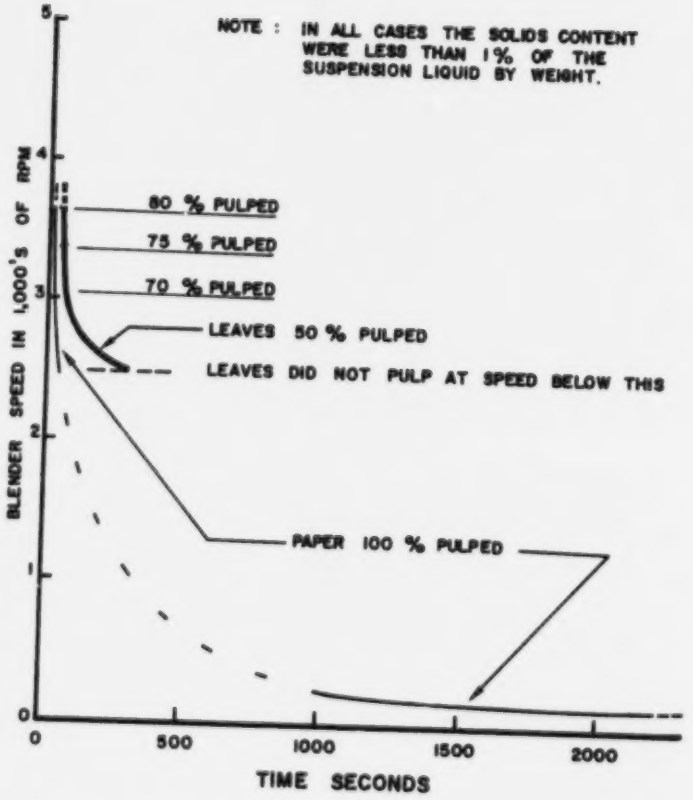
TYPICAL
UNDERGROUND INCINERATION
PILOT PLANT

PLATE XXVI





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ENGINEERS

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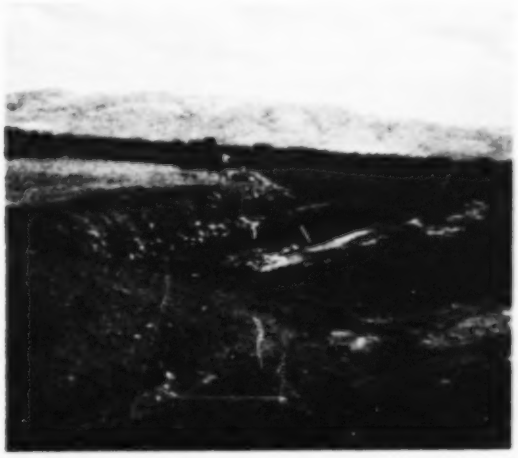
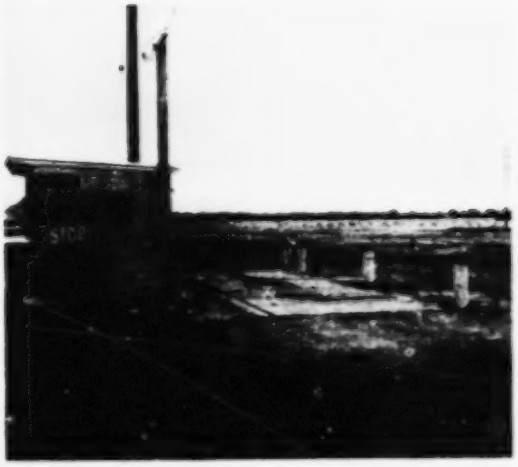
PULPING EXPERIMENT

PLATE XXVII

1.
Test Site Prior to
Landfill Construction



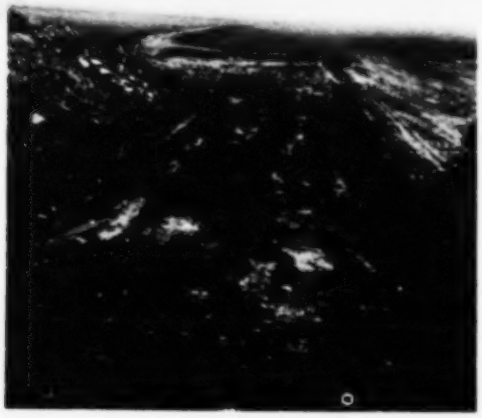
2.
Typical Cut and Cover Operation
at Santa Clara Landfill



3.
Weighing Scale and
Weigh Masters Quarters

4.
One-Man Collection Vehicle

5.
Anaerobic Test Cell
Excavation and Recompaction



6.
Typical Anaerobic Cell
Prior to Filling

7.
Caterpillar Tractor D-9

8.
FWD Wagner WC-17

Reproduced from best available copy.

9.
Inspection of Excavation Prior to Installment of Demonstration Cell
January 1967

10.
Excavated Demonstration Cell and Partially Installed Underdrain after Rains February 1967

11.
Asbestos Cement Stockpiled for Winter Surfacing of Landfill Site Access Road

12.
Completed Aeration Cell Prior to Placing Refuse
May 1967

13.
Northerly View of Aeration Cell

P.G.& E. Power Line

14.
Air Blower at Aeration Cell

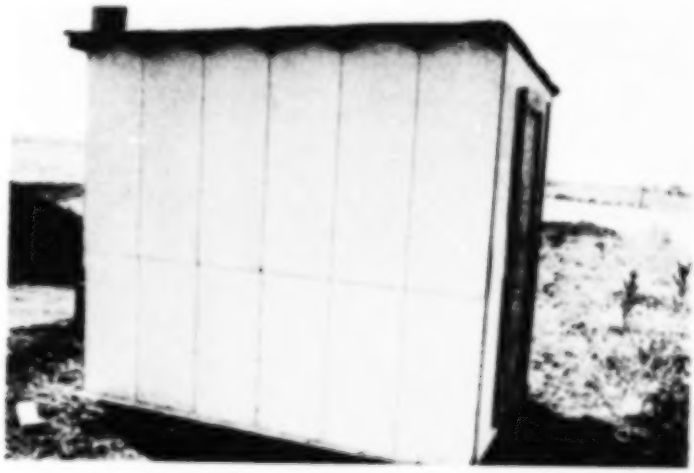
15.
Access Well with Sampling Ports
Aeration Cell May 1957

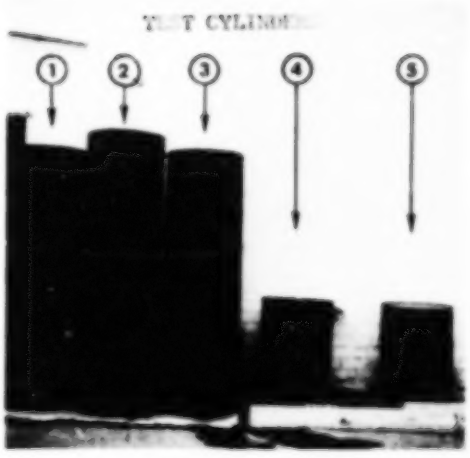
16.
Workers Installing Perforated Vitrified Clay Aeration Under Drain System May 1967

17.
Typical Refuse Placed in Aeration Cell May 1967

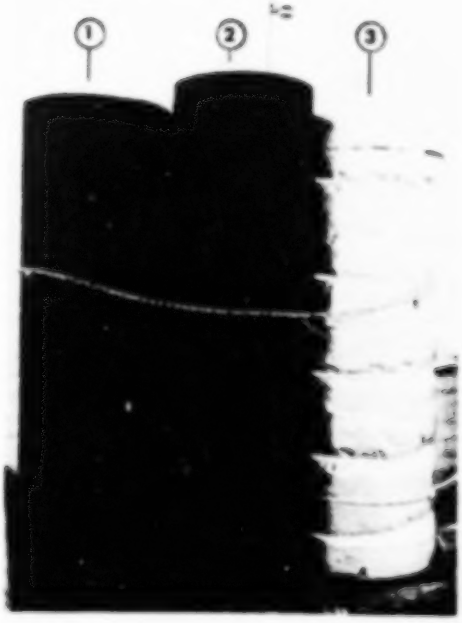
18.
D-9 Caterpillar Compacting Refuse to Depth of 7 ft in Aeration Cell During Shakedown Test June 1967

19.
Work Shed at Site



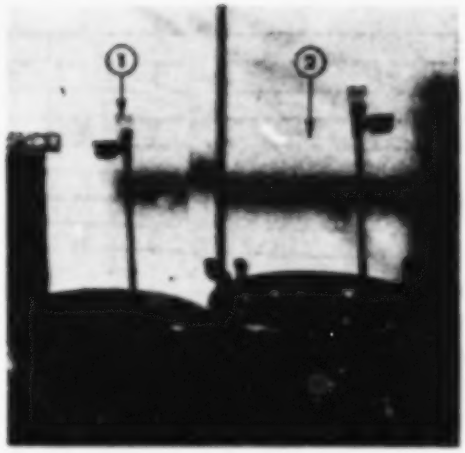


20.
Pilot Plant Test Cylinders
Nos. 1 - 3 employed for Replicating Aerobic Biological Decomposition and Nos. 4 - 5 for Underground Incineration



21.
Close-up of Test Cylinders 1, 2 and 3

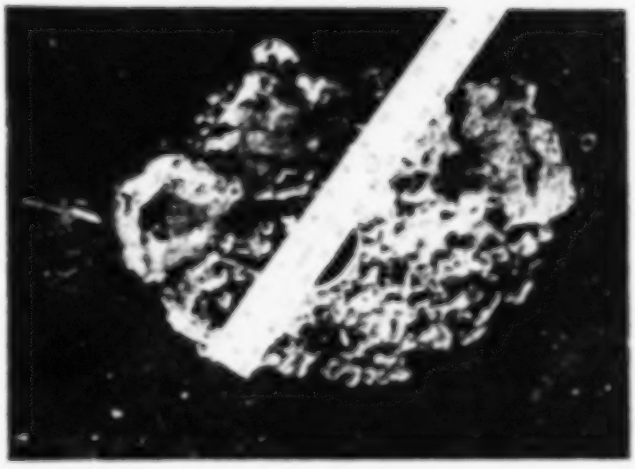
Note Cylinder 3 with 4" thick fiberglass insulation blanket.



22.
Pilot Plant Test Cylinders with Tensiometers in Refuse and Soil Blankets

23.
Close-up of Underground Incineration Test Cylinder 4

Note Air Inlet and Effluent Gas Discharge



24.
Residue from Underground Incineration Test, Photograph 23

Note Glassy Texture and Complete Residue Oxidation

APPENDIX 1

BIOGRAPHIC INFORMATION

The following are brief biographic sketches of the Project Engineer's professional personnel engaged in this project:

A. Ralph Stone

Born April 2, 1921, at New York, New York

BS in Engineering, 1943, University of California (Berkeley)
MS in Civil Engineering, 1944, University of California (Berkeley)

1944-1946, U. S. Public Health Service
1946-1948, U. N. World Health Organization (in China)
1948-1949, Inst. of Inter-American Affairs (Colombia, S.A.)
1949-1951, Research Assoc., University of California (Berkeley)
1951-1953, Project Engineer, Fluor Corp., Los Angeles, California
1953-date, Research Assoc., University of Southern California, and Consulting Sanitary Engineer in private practice, President, Ralph Stone and Company, Inc., Engineers.

Registered Professional Engineer
Member ASCE (F), AWWA, ACS, WPCF, APHA, APWA, RSH, ASPO, SCPO.
Senior Sanitary Engineer, USPHS (Inac. Res.)
Certified by ASEIB

B. Earl T. Conrad

Born February 19, 1936, at San Francisco, California

BS in Engineering, University of California (Berkeley)

Mr. Conrad has been a project manager supervising field investigations for the engineering of public works and industrial plants; recently he completed assignments for water, sewage, reclamation, and solid wastes projects in Ventura, Boron, Mammoth Lakes, Lake Berryessa, and Los Angeles. Throughout his distinguished career, Mr. Conrad has been able to organize assignments and to work well with interested officials. His past involvement in private, commercial, and municipal and Federal projects has ranged from construction supervision and surveying to research and development studies.

Registered Professional Engineer
Member ASCE, NSPE, Chi Epsilon

C. Marion S. Israel

Born August 17, 1915, at Fort Wayne, Indiana

BS in Engineering, 1938, University of California (Berkeley)

Mr. Israel has been associated with the Project Engineers since 1955 in the capacity of a senior staff member. He is experienced in all phases of refuse collection and disposal and related water, sewage and environmental studies. He is particularly competent in planning, management, data and program analysis and coordinating field and office project studies. He resides at Santa Clara, California.

Registered Professional Engineer.

APPENDIX 2

RULES AND REGULATIONS
GOVERING OPERATION OF A SANITARY LANDFILL
BY THE CITY OF SANTA CLARA

SECTION I - LEGAL BASIS

These Rules and Regulations Governing Operation of a Sanitary Landfill by The City of Santa Clara are in accordance with Article IV of Chapter 13 of "The Code of the City of Santa Clara, California".

SECTION II - GENERAL RULE

No person, firm, or corporation shall dump or dispose of any garbage or refuse on the land utilized by the City of Santa Clara for a sanitary landfill except in compliance with all of the provisions contained herein and Article IV of Chapter 13 of "The Code of the City of Santa Clara, California".

SECTION III - AREA REGULATIONS

1. The landfill area shall be open to the public from 8:00 A.M. to 5:00 P.M., Monday through Saturday except for the following holidays: January 1 (New Year's Day), May 30 (Memorial Day), July 4 (Independence Day), the Thursday set aside in November for Thanksgiving Day, and December 25 (Christmas).

2. Smoking, scavenging, or salvage operations of any kind or nature are prohibited in the landfill area.

3. Dumping shall be permitted only in areas designated by the gate attendant.

4. No pet, or child under the age of twelve years, shall go upon, or be permitted to go upon, the landfill area except while in the confines of a motor vehicle.

5. Access to the landfill area shall be permitted only at the points designated by the gate attendant.

6. Dumping shall be limited to the hours of operation.

SECTION IV - PROHIBITED OR RESTRICTED MATERIALS

1. All loads may be subject to inspection by the gate attendant for the purpose of determining if a load contains prohibited or restricted materials which may create a hazard or constitute a nuisance in the landfill area.

2. The following are designated as prohibited materials and shall not be accepted for disposal at the landfill area.

a) Wet garbage.

b) Automobile bodies. Individual automobile parts such as fenders, hoods, and doors will be accepted.

c) Explosives and other highly volatile materials.

d) Hot ashes

e) Tree stumps or branches over 36 inches in circumference, or loads of tires discarded by a commercial business enterprise.

f) Bulk or extremely heavy items (such as large tree parts) which because of size or shape cannot be readily handled by the equipment currently in use at the facility.

g) Any material which the gate attendant, because of character or quantity, considers hazardous or detrimental to the efficiency and sanitary operation of the facility.

SECTION V - SCHEDULE OF FEES

For the purpose of fee collection, fractional or partial loads shall be considered as full loads and the appropriate fee schedule applied.

Classification	Resident Rate	Non-Resident Rate
Loaded passenger car or station wagon; empty passenger car or station wagon equipped with a two-wheel trailer.	$0.25	$0.50
Loaded passenger car or station wagon equipped with a two-wheel trailer; ½ ton pickup truck.	0.50	1.00
All other vehicles or trailers	0.50 per ton	1.00 per ton

Inoperative Scales

In the event the vehicle scales provided at the landfill area become inoperative, the following alternate schedule of fees shall apply to the "All other vehicles or trailers" classification in the weight category. The gate attendant shall estimate the volume of refuse for payment purposes.

Resident Rate	Non-Resident Rate
$0.25/cubic yard	$0.50/cubic yard

All fees shall be paid to the gate attendant prior to the discharge of materials upon the landfill area.

Resident Identification

A resident is defined as "any person residing within the corporate limits of the City of Santa Clara." It is the responsibility of persons claiming eligibility for Resident rates to establish the fact of their residency by presentation of a valid California Driver's License or Vehicle Registration Certificate bearing a City of Santa Clara address. Fees collected because of failure to prove residency shall not be refunded.

SECTION VI - FILL MATERIALS

Clean earth, rock, broken asphalt and masonry, are classified as fill material and will be admitted in any quantity not inconsistent with these rules and regulations without payment of fee, providing there is a current need for fill material as determined by the gate attendant. If no need exists, fill material will be accepted subject to the Schedule of Fees in Section V.

Mixed loads which contain refuse as well as acceptable fill material shall be classified as refuse, and payment of fees shall be in accordance with Section V- Schedule of Fees.

APPROVED BY THE CITY COUNCIL OF THE CITY OF SANTA CLARA ON Sept. 14 1965.

APPENDIX 3

STATE OF CALIFORNIA
REGIONAL WATER QUALITY CONTROL BOARD
SAN FRANCISCO BAY REGION

RESOLUTION NO. 713

PRESCRIBING REQUIREMENTS AS TO THE NATURE OF WASTE DISCHARGE BY THE CITY OF SANTA CLARA ONTO LAND AT A 69 ACRE LANDFILL AREA LOCATED BETWEEN LAFAYETTE STREET AND COFFIN ROAD APPROXIMATELY 3300 FEET SOUTH OF HIGHWAY 237, SANTA CLARA COUNTY

I. WHEREAS, a Report on Waste Discharge, dated September 20, 1965 was filed, in accordance with Section 13054 of the State Water Code, with this Regional Water Quality Control Board by the City of Santa Clara, hereinafter referred to as the discharger, on September 22, 1965; and

II. WHEREAS, said report and other data submitted by the discharger, provide the following information:

A. The waste will consist of dry material and rubbish and fill materials defined as clean earth, rock, broken asphalt, and masonry; the following materials are designated as prohibited in the rules and regulations approved by the City Council on September 14, 1965:

1. Wet garbage

2. Automobile bodies, - individual automobile parts such as fenders, hoods, and doors will be accepted

3. Explosives and other highly volatile materials

4. Hot ashes

5. Tree stumps or branches over 36 inches in circumference, or loads of tires discarded by a commercial business enterprise

6. Bulky or extremely heavy items (such as large tree parts) which because of size or shape cannot be readily handled by the equipment currently in use at the facility

7. Any material which the gate attendant, because of character or quantity, considers hazardous or detrimental to the efficiency and sanitary operation of the facility;

B. The amount of waste to be deposited is estimated at 72,000 cubic yards per year initially, increasing to 90,000 cubic yards per year by 1975;

C. The waste will be disposed of in a sanitary cut and cover landfill on a 69 acre site located between Lafayette Street and Coffin Road approximately 3300 feet south of Highway 237;

D. The discharger proposes to take the following steps to exclude surface and rain waters from contact with fill materials:

1. The surface of the fill will be sealed with six (6) inches of earth within forty-eight (48) hours of deposit

2. The completed fill will be covered with not less than twenty-four (24) inches of compacted earth

3. The toe of finished fills will terminate in a dike or ditch filled with sand, gravel, or both to prevent puddling and to accelerate drainage

4. Cracks, depressions, and erosion of the surface and side slopes of the completed fill will be promptly repaired during the operational life of the site

5. The finished surface will be graded to precise drainage plan, copy of which was transmitted with discharger's report;

E. The discharger proposes to excavate the native material in the disposal area to a depth of approximately eight feet maximum;

F. The estimated active life of the landfill operation is eleven years; and

III. WHEREAS, the Board has received and considered the following correspondence regarding this waste discharge:

A. Memorandum from the State Department of Public Health, Bureau of Sanitary Engineering, dated October 13, 1965;

B. Memorandum from the State Department of Water Resources, dated October 14, 1965;

C. Memorandum from State Department of Fish and Game, dated November 16, 1965;

D. Letter from Santa Clara County Flood Control and Water District, dated October 18, 1965;

E. Letter from the Santa Clara County Health Department, dated October 18, 1965; and

IV. WHEREAS, investigation by the staff of the Board discloses that:

A. San Tomas Aquino Creek borders the disposal site along part of its westerly boundary and it is presently tidal up to Coffin Road; this channel will be improved in 1966, at which time it will become tidal to a point upstream from the disposal site; because of recent improvements in the channel of Guadalupe River, flooding hazards in the area are minimal, and the hazard will be further reduced when San Tomas Aquino Creek is improved;

B. Land uses near the waste disposal site include:

1. Highway and rail transportation

2. Industrial

3. Residential

4. Agriculture; now

V. THEREFORE BE IT RESOLVED, that it is the intention of this Regional Water Quality Control Board to:

A. Prevent nuisance, as defined by Section 13005 of the State Water Code, from being caused by this waste discharge or by treatment or conveyance of wastes tributary thereto;

B. Prevent degradation of ground and surface water in the vicinity of the disposal site;

C. Prevent hazards to public health;

VI. BE IT FURTHER RESOLVED, that in order to fulfill its intentions in the preceding paragraph, this Board prescribes the following requirements for this waste discharge:

A. FOR THE PREVENTION OF NUISANCE
The discharge shall not cause:

1. Organic refuse at any place in water or in a position where it can be contacted by surface runoff or ground water;

2. Atmospheric odors recognizable as being of waste origin at any place outside the disposal site;

B. FOR THE PROTECTION OF BENEFICIAL WATER USES

1. Pursuant to Section 13054.3 of the California Water Code this Regional Board prohibits the disposal of industrial wastes other than solid inert wastes classifiable as group 3 dump materials by the Department of Water Resources, industrial or agricultural chemicals or any liquid or solid wastes other than dry material and rubbish in this dump at any time

2. Wastes deposited at this site shall be prevented from contacting surface runoff water at all times

3. Wastes deposited at this site shall be prevented from contacting ground water at all times by limiting all excavation to not less than one foot above high ground water level;

VII. BE IT FURTHER RESOLVED, that these requirements are predicated in part on drawings and other data submitted to this Board on September 22, 1965 and which show measures proposed by the discharger to protect the disposal area from surface waters;

APPENDIX 4

ECONOMIC COMPARISON OF VARIOUS SOLID WASTE DISPOSAL METHODS

1. Alternative Evaluations

   Scheme I: Incineration followed by land disposal of combustion residue and inerts.

   Scheme II: Normal sanitary and fill practice using either "deep" or "shallow" procedures.

   Scheme III: Composting followed by land disposal of product.

   Scheme IV: Controlled aeration of sanitary fill followed by final land disposal.

2. Population Served: 100,000.

3. Refuse Production Quantity: 5.0 lb/capita/day = 500,000 lb/day (250 tons/day)

4. Location: Typical New York and California community.

5. Type of Refuse: Normal domestic.

SCHEME I - INCINERATION

Plant Capacity: 250 tons/day = 91,250 tons/year = 18.25×10^7 lb/year.
Plant located on a five acre site.

Raw refuse composition, % by wet weight.

Typical Analysis, 1966, Santa Clara, California	Typical Analysis, 1965 N.Y. Public Health Dept.	Use
% Volatiles = $\frac{100\ (101\ \text{lbs})}{(192\ \text{lbs})}$ = 53	45	50
% Inerts = $\frac{100(192-101-.38X192)\ \text{lbs}}{(192\ \text{lbs})}$ = 9	25	25
% Moisture = 38	30	25

The incinerator plant ash is assumed to have the following characteristics:

90% Destruction of Volatiles
20% Moisture

Appendix 4 (Continued)

Annual weight of ash and inert materials to landfill for disposal (10^7 lb/yr):

Volatiles	(18.25)	(.50)	(.10)	= 0.91
Inerts	(18.25)	(.25)		= 4.56
Subtotal, exclusive of moisture				5.47
20% Moisture				1.09
TOTAL				6.56

From the foregoing materials balance the percentage of raw refuse by dry weight being disposed of to a landfill: $100 \times \frac{5.47}{13.70} = 40\%$

NOTE: Los Angeles County Sanitation Districts data indicates that 52% of total refuse production will be disposed in a landfill. Their data indicates a larger percentage of inerts (36 vs 25%) than the above materials balance estimate.

Landfill density: 1,000 lb/cu yd on a dry weight basis + 20% moisture = 1,200 lb/cu yd on a wet weight basis.

Landfill volume per year:

$\frac{6.56 \times 10^7 \text{ lb}}{1.2 \times 10^3 \text{ lb/cu yd}}$ = 54,700 cu yd = 34 ac-ft + 20% for clean fill and buffer zones

Use 41 ac-ft/yr

SCHEME II - SANITARY LANDFILL

Total weight to landfill: 18.25×10^7 lb/yr.

Landfill density:
750 lbs/cu yd on dry weight basis
+ 33% moisture = 1,000 lb/cu yd on a wet weight basis.

Landfill volume per year:
$\frac{18.25 \times 10^7 \text{ lb/yr}}{10^3 \text{ lb/yr}}$ = 182,500 cu yd = 113 ac-ft + 20% for clean fill and buffer zones

Use 136 ac-ft/yr

SCHEME III - COMPOSTING

From Los Angeles County Sanitation Districts estimates:

50% of raw refuse receives direct burial, and 50% is volatile matter which can be composted with a corresponding decrease in weight ranging from 20 to 50%; for the purpose of this evaluation assume a 30% weight reduction. Assume the compost is not re-used and that it is disposed of in the landfill. Thus 85% of raw refuse is deposited in the landfill.

Total weight to landfill:

$$(0.85)\ (18.25 \times 10^7\ \text{lbs/yr}) = 15.5 \times 10^7\ \text{lbs/yr}$$

Landfill density: 800 lbs/cu yd on a dry weight basis + 33% moisture.
1,070 lbs/cu yd on a wet weight basis.

Landfill volume per year:

$$\frac{15.5 \times 10^7\ \text{lb/yr}}{1070\ \text{lb/cu yd}} = 145{,}000\ \text{cu yd} = 90\ \text{ac-ft}$$

+ 20% clean fill and buffer zone

Use 108 ac-ft/yr

SCHEME IV - CONTROLLED AERATION

This method consists of a series of "combustion" cells which discharge their stabilized material into "permanent deposition" cells. It is assumed that 40% of the volatiles are oxidized in 60 days, after which the oxidized material or residue is transferred to "permanent deposition" cells.

Combustion cell requirements:

In-place density = 1,000 lbs/cu yd (wet weight basis).
13 Days to fill aeration cell.
Require 6 cells for continuous operation.
Total Area = 3 ac/cell including "permanent final deposition area
X 6 = 18 ac for continuous disposal/processing.
Total weight for permanent refuse disposal: (10^7 lb/yr).

Inerts	=	4.7
Volatiles (0.6) (9.13)	=	5.5
Subtotal, exclusive of moisture	=	10.2
33% Moisture	=	3.4
TOTAL		13.6

From the foregoing materials balance, the percentage of initial refuse by dry weight disposed to the permanent fill = $100 \times \frac{10.2}{13.70} = 75\%$

Landfill density: 850 lb/cu yd on a dry weight basis + 33% moisture =
1,130 lb/cu yd on a wet weight basis.

Landfill volume per year:

$$\frac{13.6 \times 10^7\ \text{lb}}{1130\ \text{lb cu yd}} = 120{,}000\ \text{cu yd} = 75\ \text{ac-ft}$$

+ 20% for clean fill and buffer zone

= 90 ac-ft/yr

Assuming a refuse depth of 12, disposal area required = 7.5/yr
Use 2 1/2 cells per year.

Appendix 4 (Continued)

SUMMARY OF ADDITIONAL COSTS FOR CONSTRUCTION AND OPERATION OF AERATION CELLS

Class	No.	Item	Total Cost ($)	No. of Times Used	Cost Per Cell ($)
A.		Special Construction:			
	1.	Under drain	5,000	1	5,000
	2.	Connecting pipe to under-drains (serves 2 cells)	2,000	1	1,000
	3.	Each blower serves 2 cells	3,000	6	250
	4.	Power service connection			200
	5.	Irrigation system (Each serves 2 cells)	1,200	6	100
	6.	Water service connection.			100
	7.	Power consumption 4 kw X 24 hr/day X 180 days X $.02/kwh			340
	8.	Water use, 4 in/mo X 2 mo X 1/12 ft/in X $150/ac-ft X 3 ac			300
		TOTAL			7,290
B.		Landfill excavation and embankment: No cost above cost of normal cut and cover.			
C.		Refuse handling: Extra cost for initial placement and compaction of refuse in aeration cell : $.10/cu yd of raw refuse			
		Yardage handled : 61,000 cu yd/cell @ $.10/cu yd :			6,100
D.		Residue transfer : extra cost of transferring from aeration cell to final disposal area = $.22/ cu yd of residue per cell			
		Yardage handled : 46,000 cu yd/cell @ $.22/cu yd :			10,120
		Total cost of Aeration System Per Cell			23,510
		Unit cost : $.51/cu yd in-place .90 ton in-place .68 ton of raw refuse			

APPENDIX 5

SUMMARY OF TEST PROCEDURES

1. Refuse Composition

Refuse is classified into the following categories:

Paper	Yard Trimmings	Inerts	Garbage
Paper	Grass	Glass	
Rag	Hedge	Plastics	
	Wood	Metal	
		Ceramics	

Percent by volume of each type of refuse is determined by measuring containers. The weight of each type of refuse is also recorded. A moisture content analysis is run on samples taken from each of the four basic classes. The initial volume of the aggregate refuse installed in each cylinder is measured, and density and dry weight of refuse are calculated.

2. Temperature and Relative Humidity

Relative humidity is recorded on an Abbeon Relative Humidity Indicator.

Maximum and minimum ambient air temperature readings are measured on an Abrax Max-Min Thermometer. Official U.S. Weather Bureau data is used to supplement this information.

The air supply temperatures are recorded weekly by means of a pitot orifice in the air intake line ahead of each cylinder. Temperatures in the refuse and soil blanket of each cylinder are monitored weekly by means of thermistors connected to a central TELE-Thermometer, YSI, Model 425C, Indicator. Two to four probes are installed in each cylinder. All temperatures are read directly in Centigrade and converted to Fahrenheit.

3. Settlement

Settlement or each cylinder is recorded at least weekly after compaction. Compaction is equivalent to a weight of 200 lbs falling a distance of 1/2 ft about 25 times. The amount of settlement is measured by means of averaging the readings across each cylinder. Volume reduction is calculated per the following formula:

$$\% \text{ Reduction} = \frac{\text{Initial Volume} - \text{Reduced Volume}}{\text{Initial Volume}}$$

4. Air Supply

A continuous air supply into each aerobic cylinder is provided by an air pump and/or a heavy duty spiral blower. Gate valves and Dwyer flowraters control and indicate the air flow into each cylinder. The air flow to each cylinder is recorded periodically.

5. Burner Operation

The burners in Cylinders 4 and 5 are used to ignite the refuse. They are electrical charcoal lighters. The duration of burner operation is noted.

6. Gas Analysis by Chromatograph

Gas composition within the refuse is determined weekly, or more frequently if required. Periodically, gas samples are also extracted from the soil cover. A Gelman "Little Giant" Model 13152 Pressure/Vacuum Pump is used to extract these samples from probes in the cylinders through 1/4 inch plastic hose into evacuated 250 ml glass collecting tubes. A Varian Aerograph A90-P3 Chromatograph is used for CO_2, N_2, O_2, CH_4, and CO analysis. A Leeds and Northrup Speedomax W Chart Recorder with a disc chart integrator, Model 224 points out the composition on a volumetric basis. The accuracy of the chromatograph is periodically checked by means of standard samples containing 70 percent N_2, 15 percent O_2, 5 percent NH_4, 5 percent CO_2, and 5 percent CO.

7. Gas Analysis by Orsat

Gas composition is also determined by means of a Hays Orsat Analyzer, Model 621.21.20, to check the Chromatograph analysis. Gas samples are taken from two probes in each cylinder, one in the soil and one in the refuse.

The sample is pumped directly into the Orsat, using a rubber bulb pump and 1/4 inch nylon tubing. Volume percentages of CO_2 and O_2 are determined and recorded.

8. Oxygen Analysis

A Beckman Model 778 Process Oxygen Analyzer is operated continuously to check the amount of oxygen in Cylinder 2 (aerobic). Periodic readings are taken and any fluctuations observed are recorded.

9. Moisture Analysis

Moisture content analyses are performed on the refuse and soil cover of each cylinder and of each cell when they are loaded. Moisture content is also determined during operation of Cylinders 1, 2, and 3 by extracting refuse samples through a manually plugged 1-1/4 inch opening. Moisture content of the incinerated refuse (Cylinders 4 and 5) is determined during strip-down.

The refuse samples are weighed, then dried in a Cenco oven at a temperature of 103° C. An Ohaus Cent-O-Gram Triple Beam Balance and a Welch Triple Beam Balance are used for weighing. The moisture content is calculated by the following formula: Moisture Content = $\frac{\text{Wet Weight} - \text{Dry Weight}}{\text{Dry Weight}}$

10. Water Application

Water is added to the refuse as needed during the initial set-up of each cylinder in order to increase the moisture content to the desired level. Water is also added to the soil cover when required to maintain a

10. Water Application (Continued)

moisture level adequate to seal the cylinder, prevent surface cracks, and minimize odors. The amount of each addition, including the amount of water due to rainfall, is recorded.

11. Organic Content

The organic content of the refuse is determined after completing the moisture analysis, using the samples after they have been dried.

The samples are weighed in tared ceramic crucibles and muffled in a Thermolyne Type 1400 Muffle Furnace at a temperature of 600° C. for 60 minutes. The samples are re-weighed and the percent by weight of organic matter is calculated by the following formula:

$$\text{Organic Content} = \frac{\text{Muffled Weight}}{\text{Dry Weight}}$$

12. Odor Analysis

An odor analysis is performed weekly in accordance with Standard Methods.

13. Manometer

Pressure in the test cylinders is measured weekly, using a manometer calibrated in inches of water. A reading is taken at each gas probe while air is being delivered to the cylinders.

14. Post-Incineration Test Analyses

After completing each oxidation run, the cylinder's soil blanket is stripped and the refuse is classified in accordance with the state of decomposition, odor, volume, weight and other visual characteristics. Moisture content and organic matter are determined as described above.

15. Cellulose

Cellulose forms the structural fiber of many plants. Its general

15. Cellulose (Continued)

formula is $(C_6 H_{10} O_5)_x$ where x varies from 100 to about 200. Biological degradation presumably involves hydrolysis to glucose as the first step.

Cellulose is used for the manufacture of a wide variety of products. In various combinations with other matierals, it serves as the basic substance in all paper products. Cellulose is the most widely distributed organic substance in nature. Its proportion to the (total) decomposable substances is relatively high.

About 80 percent to 90 percent of the cellulose present in raw refuse is broken down by composting. Determination of both the cellulose content and its percentage of the total and assimilable organic matter at various degrees of composting, may provide a good index for intensity of decomposition and degree of maturity of compost.

For determination of cellulose in heterogeneous materials, such as refuse or refuse-sludge compost, extraction with Sahwiezer reagent (copper ammonium complex, Methods: Hueser 1946, Doree' 1947) has proven good. Extracted cellulose is precipitated with acid and gravimetrically determined. Viscosity meter determinations are unsuitable as compost cellulose has been largely decomposed.

16. Gross and Net Calorific Value

Equipment: Parr Oxygen Bomb Calorimeter, Series 1300 (isothermal jacket); Parr Oxygen filling connection, Series 1823, oxygen cylinder (standard commercial); trip balance, net capacity 3,000 to 5,000 gr; pressure regulator (standard commercial); drying oven; desiccator; analytical balance.

Reagents: Distilled water, sodium carbonate solution, 1.0725 N; sodium or potassium hydroxide solutions of the same normality are acceptable. Methyl orange or Methyl red indicator

16. Gross and Net Calorific Value (Continued)

Reference: "Tentative Methods of Analysis of Refuse and Compost," reprinted from Municipal Refuse Disposal, compiled and edited by the Refuse Disposal Committee of the American Public Works Association with the assistance of the U.S. Public Health Service, published in 1961 by the Public Administration Service, 1313 E. 60th Street, Chicago, Illinois.

APPENDIX 6

CITY OF SANTA CLARA, CALIFORNIA

PHS DEMONSTRATION GRANT NO. 1-D01-SW-00018-01
SUPPLEMENT

LAND RECLAMATION BY ACCELERATED STABILIZATION

RELATED STUDIES OF COMPACTION EQUIPMENT

GENERAL

To supplement the solid waste demonstration now underway it is proposed to quantitatively study the technical, economical and environmental aspects of improved landfill compaction with various types of mechanical equipment. The existing truck scales, equipment and personnel will be used at the sanitary landfill site to weigh, place and compact domestic refuse. The City has been using conventional equipment (a D-9 Caterpillar and F. W. Wagner WC-17) for the past 1½ years and has been considering modifying the Wagner by replacing the rubber tires with steel tires. By conducting this supplementary test program concurrently with the authorized demonstration, maximum benefits can be realized at minimum cost.

Basically the study is envisioned as a two phase program to compare the densities achieved using conventional and improved methods and equipment. The first one-half year period Phase I effort will be to analyze operating conditions using existing equipment and determine the in-place densities achieved with normal compaction equipment. This study will provide a base line for Phase II studies. At the end of six months the rubber tires on the F. W. Wagner will be replaced with steel tires (transforming the Wagner to a SF-17 classification), and the Phase II (one and one-half years) program will be initiated. Essentially the densities resulting from operating the F. W. Wagner SF-17 will then be compared with those achieved using the D-9 Cat and those previously determined. The available compaction equipment and authorized demonstration work underway will significantly reduce the cost of these studies.

DETAILED APPROACH PHASE I

1.0 Investigate in-place densities of existing anaerobic landfills.

1.1 This will provide supplemental control data for comparing the densities achieved during the past 1½ years of operation with the densities achieved during this proposed two year compaction demonstration study.

1.2 The general approach for determining existing in-place density is outlined in Appendix 2.

1.3 At least 4 density determinations will be made in each of 4 cells.

1.3.1 Existing cells are 30' wide and vary in length up to 200'.

1.3.2 The existing cells to be tested contain domestic refuse with some industrial wastes.

1.3.3 The age of the cells vary from 1 to 18 months.

1.3.4 Refuse removed from the excavations will be sampled for composition percent inerts and percent moisture. See Appendix 3 for the methods of sampling.

2.0 Determine in-place densities of new anaerobic and aerobic cells by using conventional compaction equipment only.

2.1 Construct three parallel anaerobic cells.

2.1.1 These cells will be about 30' wide by 200' long.

2.1.2 Fill and compact one with the rubber-tired Wagner.

2.1.3 Fill and compact one with the D-9 Cat.

2.1.4 Fill and compact one with both the D-9 Cat and rubber-tired Wagner.

2.2 Fill and compact the aerobic test cells.

2.2.1 The two aerated cells are each about 50'x200'.

2.2.1.1 Fill and compact one with the D-9 Cat.

2.2.1.2 Fill and compact one with the rubber-tired Wagner.

2.2.2 The residue cells will be at least 50'x100'.

2.2.2.1 Fill and compact one with the D-9 Cat.

2.2.2.2 Fill and compact one with the rubber-tired Wagner.

2.3 Regularly determine refuse compostion, percent moisture, percent inerts, etc.

2.4 Procedure for determining in-place density.

2.4.1 Excavate the cell.

2.4.2 By means of an accurate survey, determine the volume of the empty test cells.

2.4.3 Install settlement plates flush with the bottom of the cells. Typical settlement plates are illustrated in Appendix 1.

2.4.4 Fill the test cells with normal domestic type refuse collected by municipal forces. Industrial wastes will be segregated for separate disposal at another cell.

2.4.5 All trucks disposing of refuse in the test cells will be tare weighed on the City's scales to maintain a precise record of tonnage.

2.4.6 Sufficient quantities of water will be added to maintain a constant moisture content.

2.4.7 To avoid odors and maintain a sanitary condition, the refuse will be covered daily with a 6" soil mantle. After filling the cell with refuse and before placing the final 2' soil blanket measure the actual depth of the nominal 6" soil cover and install settlement plates on top of the refuse to provide accurate measurements of the volume and density of the soil cover.

2.4.8 By use of the settlement plates on the bottom of the cells, ascertain the settlement of the natural ground, if any, under the weight of refuse.

2.4.9 Accurately survey the cell prior to placement of the final soil blanket.

2.4.10 Apply the final 2' soil blanket.

2.4.11 Measure the settlement of the natural ground under the cells and the settlement of the plates located on top of the refuse fills.

2.4.12 Accurately survey the finish grade of the test cell. The data collected will provide the weight of refuse, volume of refuse and total volume of soil blanket.

2.4.13 Establish permanent bench marks on the surface of the completed test cells.

2.5 Spot check the in-place densities by performing the tests described in Appendix 2.

2.5.1 Relate these densities to those determined for the existing anaerobic cells.

2.6 With further operating experience improved operational procedures will be implemented.

2.7 Compare the densities and continuing settlement of the various test cells monthly.

DETAILED APPROACH PHASE II

3.0 Install steel tires on the F. W. Wagner and determine in-place densities of the anaerobic and aerobic cells by operating both the D-9 Cat and steel-tired Wagner in parallel in a manner similar to that described in Phase I.

3.1 Accurately determine the densities using the improved compactor (F. W. Wagner FS-17) or the conventional D-9 Cat and compare with the previously determined densities.

3.1.1 Aanerobic, aerated and residue cells similar to those described above will be constructed.

3.1.2 Certain cells will be compacted with both the steel-tired Wagner and D-9 Cat operating together. Other cells will be compacted only with the D-9 Cat or steel-tired Wagner.

3.2 Regularly determine refuse composition, percent moisture, percent inerts, etc. as outlined in Appendix 3.

3.3 The procedure for determining in-place densities will be similar to those described in Paragraphs 2.3 and 2.4 above.

3.4 Compare the densities and continuing settlements of the various test cells.

4.0 Settlement and foundation tests and other activities.

4.1 Record the settlement of all settlement plates and bench marks at regular monthly intervals throughout this demonstration.

4.2 Preloading settlement investigations will be performed on the various test cells in a manner similar to that outlined in Appendix 1.

4.2.1 Existing conventional anaerobic cells.

4.2.2 Clean earth and/or rubble fills.

4.2.3 Anaerobic cells compacted during this program with conventional equipment.

4.2.4 Anaerobic cells compacted with the Wagner FS-17.

4.2.5 Aerobic (both aerated and residue) cells compacted with the conventional and improved equipment.

4.3 Simulate strip and spread footings by loading pads on one fill (second year).

4.3.1 Measure settlement.

4.3.2 Determine differential settlement.

4.4 Reload one cell with vibratory compactor

4.4.1 Measure settlement.

4.4.2 Determine effect of vibration on adjacent areas.

4.5 Drill and sample test cells (3 times).

5.0 Investigations may be made, if suitable grinding equipment can be rented, to determine the feasibility of filling one test cell with ground-up refuse and comparing the densities achieved with those described above (second year).

6.0 Evaluation.

6.1 Develop data relating the pertinent physical factors.

6.1.1 Compactive effort.

6.1.2 Moisture content.

6.1.3 Refuse composition and effects of seasonal variations.

6.1.4 Density.

6.1.5 Foundation bearing.

6.2 Investigate land reclamation aspects of this program.

6.3 Economic analysis.

6.3.1 Disposal cost per ton.

6.3.2 Additional equipment requirements, such as scale, compactor, water, etc.

6.3.3 Additional or decreased operating costs.

6.3.4 Land value: Initial cost, ultimate use and corresponding sale value.

6.3.5 Reduction in acreage required for solid waste disposal and corresponding environmental value.

6.4 Public health and safety aspects.

6.5 Equipment life.

6.6 Operator preference.

APPENDIX 7

LANDFILL SETTLEMENT AND FOUNDATION PROGRAM
ANAEROBIC TEST CELL

PURPOSE

1. Determine foundation and settlement characteristics of a normal anaerobic landfill when pre-loaded with ten feet of soil, assimilating a KSF load.

2. Compare this with clean earth or natural soil.

3. Determine gas stabilization achieved by ten foot depth of soil cover, particularly the conversion of combustible gases to inert gases.

4. Expand this program to include aerated solid wastes after operation of the aeration and residue cells.

CONSTRUCTION PLAN

1. Select an 80' X 140' landfill area out of the way of the normal landfill operation. Forty feet of the selected site should be clean natural ground or earth fill area and 100 feet of the selected site should be in a sanitary landfill area.

2. Excavate the clean earth and/or rubble cover from the sanitary landfill in the area of the settlement plates.

3. Place four settlement plates at selected points with the 80' X 140' area. Three plates will be placed over the anaerobic landfill (in the center of the 30' wide cells) and one in the clean earth cell.

4. Install underdrain piping in the areas of the settlement plates.

5. Replace the material over the settlement plates to the existing level of the landfill.

6. Establish test bench marks immediately outside the perimeter of the fill site.

7. Place 2 inch minimum lay of rubble or other selected material on the surface so as to later distinguish the level of the two areas prior to loading.

8. Preload the fill with a 1 kip per square foot loading by placing a ten foot high natural earth fill on the 80' X 140' test site. If the side slopes of the fill exceed 2:1, the dimensions of the test area should be increased so as to maintain the 100' X 40' flat top. The fill may be placed loose; i.e., compaction is not required. Place additional perforated hose underdrain system as the fill is placed.

9. Establish bench marks on top of the fill.

TESTING PROGRAM

1. As the fill is being placed, vertical control will be maintained on the settlement plates and test bench marks outside the fill site. The settlement plates may move downward substantially during the preloading, and the test bench marks outside the fill site may tend to rise.

2. As the fill is being placed, the perforated hose and piping will be installed. They shall be tied to the stems of the settlement plates at appropriate intervals with slack S-loops so as to prevent damage during placement of the fill.

3. After completing the ten-foot fill, periodically measure the settlement (or rise) of all settlement plates and test bench marks. Initially, when the greatest settlement occurs, the elevations should be determined weekly; as the amount of settlement decreases, the intervals between measurements can be lengthened to bi-weekly or monthly. This data will formulate a settlement vs. time curve and will be indicative of the potential differential settlement problems.

4. Periodically, gas samples will be taken from several locations and analyzed for composition. This data will show the effect of loading on evolution and conversion of combustible gases and the filtering and biological treatments afforded by earth.

5. After the settlement rate decreases to a negligible amount, the preloading will be removed. Vertical control will be continuously maintained on the settlement plates and test bench marks outside the fill site during this phase of work. There may be or may not be "spring back" of the anaerobic cell.

6. Additional foundation tests will be conducted on the preloaded sites, both the clean earth and anaerobic areas.

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